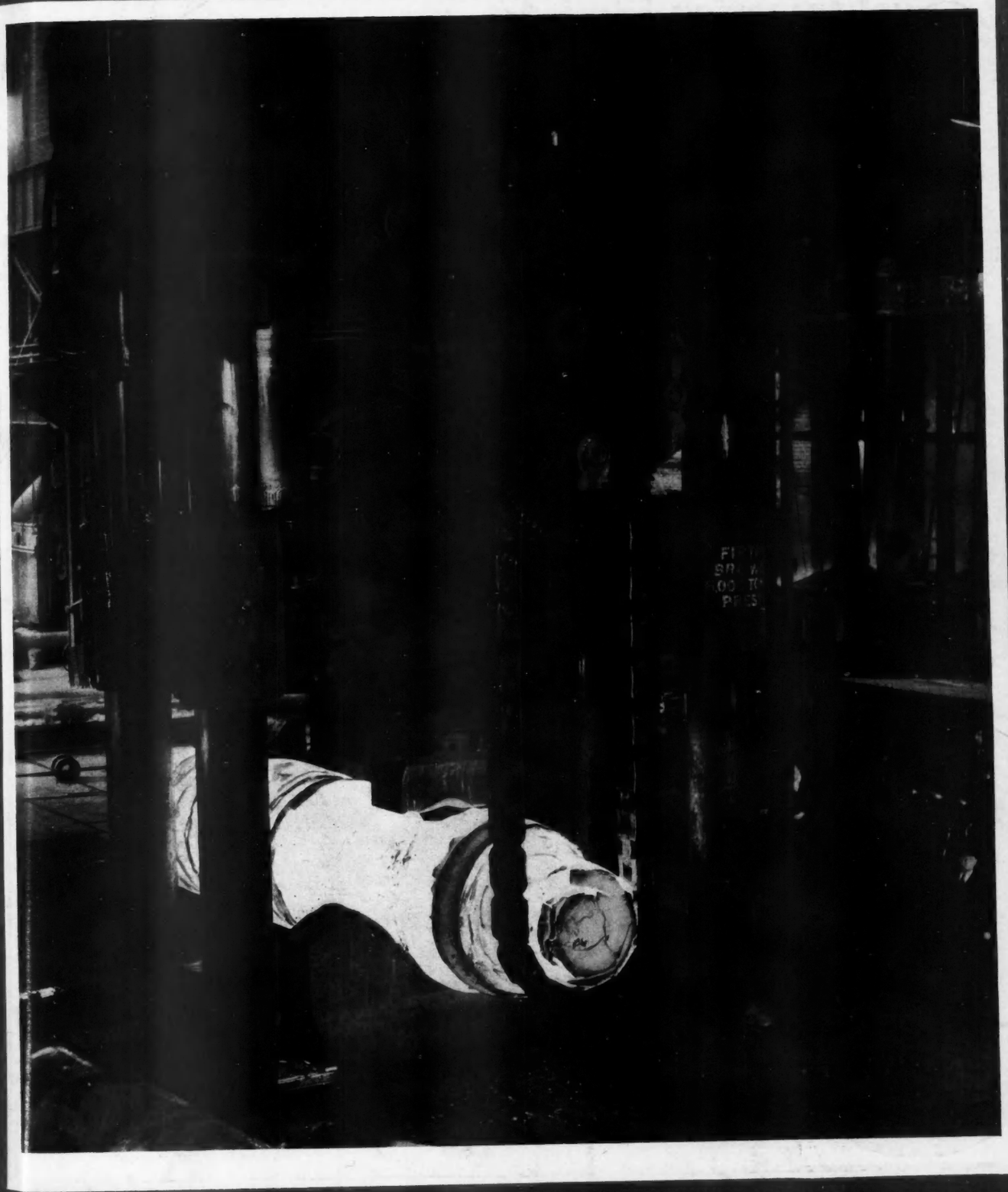
ENGINEERING

An Illustrated Weekly Journal

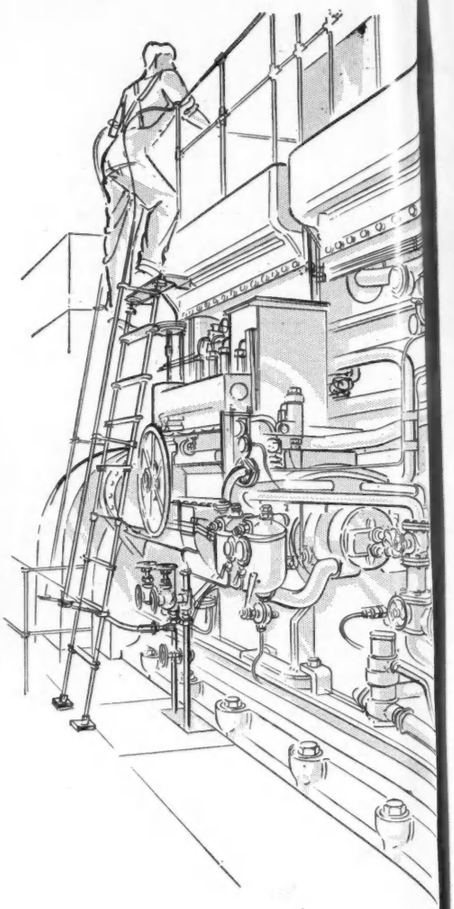
35 & 36 BEDFORD STREET, STRAND, LONDON, W.C.2 TELEPHONE: TEMPLE BAR 3663

Vol. 178 No. 4623 LONDON, FRIDAY, SEPTEMBER 3, 1954 PRICE 2s.

UNIVERSITY OF MICHIGAN
SEP 10
ENGINEERING LIBRARY



The world's largest manufacturers of Fuel Injection Equipment



For Diesel Engines of up to 500 b.h.p. per cylinder

C.A.V. fuel injection equipment for compression ignition engines is made in a range of sizes suitable for engines from the smallest portable up to large units for power station and marine duty. As the largest manufacturers of this type of equipment in the world, C.A.V. offer unrivalled experience and technical facilities to all diesel engine builders in the achievement of highest efficiency. The research and development laboratories are excellently equipped and are amongst the best in the country. World-wide service for C.A.V. equipment is provided in over 100 countries by depots and agents (including over 120 in Great Britain) where technical assistance and maintenance equipment are always available.

C.A.V.

Fuel Injection and Electrical Equipment

C. A. V. LIMITED, ACTON, LONDON, W. 3

174-52

ENGINEERING

An Illustrated Weekly Journal

Vol. 178 No. 4623 SEPTEMBER 3, 1954

Leading Article
Message from Oxford 289

Principal Articles
Aircraft Industry's Display at Farnborough 294
Flow of a Viscous Incompressible Fluid: Expressions for a Uniform Triangular Duct 298
Works Transport: Modern Equipment and Practices 300
Nimonic Alloy Developments: Extrusion Now Possible 302
Submarine Pipeline 303
345-MW Power Station at Carmarthen Bay 304
Testing Large Electrical Machines and Transformers 308
The Production of Tennis Rackets 309
Strings for Tennis Rackets: Synthetic Gut Gives Increased Strength and Resistance to Moisture and Abrasion 310
Draught Control Equipment 311
Research on Semi-Conductors 312
Two Unusual Prestressed-Concrete Buildings: Printing Works for Bank of England 315
Bowater's Paper Mill at Calhoun, Tennessee 317

Weekly Survey
Healthy Metal Markets 290
Co-ordinated Research 290
Ship Repairing 290
Easier Trade with Russia 290
How Permanent the Boom in Cars? 290
Opportunity in West Africa 291
Cutting Tools 291
Works Transport 291
Power and Paper Making 291

Contracts 292

Personal 292

Business Changes 292

Obituary 292

Letters to the Editor
Molybdenum Disulphide 293
Hiram Maxim 293
Heat Capacity of Laminations 293

Book Reviews
Rutherford by Those Who Knew Him 297
Periodicals and Serials: Their Treatment in Special Libraries 297

British Standards 297

Trade Publications 298

Books Received 298

Launches and Trial Trips 310

Notices of Meetings 319

Labour Notes 320

News
Gas-Turbine Car with Heat Exchanger 293
Self-Service in a Works Stores 293
Institution of Civil Engineers' Awards 293
Hydro-Electric Work in Scotland 293
Compilation of Instruction Manuals 296
Possible Uses of Towns' Waste 296
Polyvinyl Alcohol Films 296
Electricity Supply in July 307
Shunting Locomotives for New Zealand 311
Drakelow "B" Power Station Approved 311
Reinforced Plastic Pipe 314
Bonding Metals 319

★ ★ ★

Published every Friday by Engineering Limited
35 & 36 *Bedford Street, Strand, London, W.C.2*
TELEGRAPHIC ADDRESS *Engineering, Lesquare, London* TELEPHONE *Temple Bar* 3663

★ ★ ★

Subscription Rates for 12 *months, Inland and Abroad* £5 10*s.*, *Canada* £5 5*s. Subscriptions for periods of less than* 12 *months are based on the price of a single copy including postage* [2*s.* 3*d.*]

MESSAGE FROM OXFORD

ENGINEERS have a special interest in the message of the presidential address which Dr. E. D. Adrian delivered at the opening of the British Association meeting in Oxford. "All of us," he suggested, "scientists and laymen alike, are becoming more aware of the value of social investigation and of the degree of certainty it can bring." It is in engineering that the powers of human nature, though imperfectly understood, are allied to the powers of Nature, so much better understood, to produce the necessities and luxuries of civilised life. The engineer-administrator who co-ordinates these activities has usually received his early training in two ways: in some of the exact sciences, and in practical engineering in the shops or in the field. In the former he is educated to apply the scientific method, but in the latter, as a pupil or apprentice, he is expected to acquire an empirical understanding of human nature. By working with men on the shop floor, it is argued, he will be more competent in later life to follow his profession because he will be able to gauge the effect of his policies and instructions on those who have to implement them. There is wisdom in that conception of an engineer's education, as is shown by the normal requirements for membership of the three major engineering institutions. But it must not be allowed to discourage the rising generation of engineers from a natural desire to use every tool that the social sciences can offer them. The two approaches to human problems – that of science and that of the man with a flair for administration – must be combined.

Dr. Adrian was not pleading for his own subject ("a subject about which I know so little," he modestly remarked). His words will therefore command respect. He set himself the task of answering the question: What is there left for the British Association to do if it can only preach to the converted? Now that everyone is aware of the growing knowledge of the material world, what is the purpose of an association which is concerned with the Advancement of Science? Part of the answer, he believes, must be in showing the layman where the scientific age is leading him.

It has led him already to a world in which "we must face the possibility that repeated explosions will lead to a degree of general radioactivity which no one can tolerate or escape." The precautions normally taken to avoid the dangers of contamination when atomic energy is used to supply power to industry would soon be set aside in a major war. No doubt a country of small area like ours could be utterly destroyed by a relatively small mass of explosion, but a long war between powers well armed with atomic weapons would certainly involve an order of radioactive contamination which would destroy us all, victors as well as vanquished. That was the prospect envisaged by the President. He discounted the current argument based on the premise that war does not pay. In that he was right, because although the existence of atomic bombs may serve, in certain circumstances, as a deterrent to war, it would be the worst possible kind of escapism to vest all hope in that assumption.

The positive action which scientists must take, Dr. Adrian holds, is to make our behaviour worthy of our increased knowledge in order that we may live safely. They must make it their task at meetings such as that of the British Association to point out that the human race cannot stand more than a few thousand large atomic explosions, whether they hit their target or miss it. It may be, as he said, optimistic to think that our dangers would recede if we had a better understanding of human reactions, and it is certain that such a better understanding could itself be used for waging war more effectively. But it could be used for defence as well as attack and it is, after all has been said, about the only useful contribution that science can now make to break the vicious circle which it has created.

Social scientists work in a field that is far more complex than that of their colleagues in other subjects. The men and women whose behaviour he studies differ from each other in so many respects that it is difficult to ascertain the roots of their differences, but the general principles which determine their behaviour, Dr. Adrian said, ought to stand out when we deal with millions rather than with individuals. It is perhaps in studying men at work rather than in their private lives that the most fruitful results can be obtained. A number of research projects of this type are in progress at present, and as the results are published in the next few years they will undoubtedly increase general confidence in social science. In Dr. Adrian's view such work deserves the support not only of national and international funds: "it is too important a plant to be left in the hot-house atmosphere of research institutes and Unesco teams." If, as his address suggested, the universities are to take a greater part in this work, a complementary effort can be made by industry. Friction and inertia are familiar concepts in engineering. In the context of social science, engineers are in a unique position to answer Dr. Adrian's call.

Weekly Survey

HEALTHY METAL MARKETS

The heavy increase in the consumption of non-ferrous metals in the United Kingdom testifies to the high level of activity in the engineering industry. In the first half of 1954, 30 per cent. more zinc, 27 per cent. more copper, 14 per cent. more tin and 9 per cent. more lead were consumed than in the first half of 1953.

In the United States, on the other hand, consumption has fallen considerably, as a result of the recession, in the first half of 1954. For example, 22 per cent. less zinc was consumed than in the first half of 1953. The trend in the United States naturally weakened the metal markets but prices have been rising since the end of 1953. The international tin agreement has so strengthened the market for tin that the Board of Trade price index was 16 per cent. higher in July, 1954, than in December, 1953. The elimination of large Chilean stocks has helped to bring stability to the copper market. Lead and zinc increased in price by about 6 and 4 per cent. respectively, but there has been an underlying weakness in the market due to the heavy stocks in producers' hands in the United States. This weakness has now been removed by President Eisenhower's announcement that increased purchases of domestic supplies would be made for stockpiling and these " could total up to 200,000 tons of lead and 300,000 tons of zinc in the year ending June 30, 1955."

President Eisenhower's action is of course intended primarily to benefit the lead and zinc producers in the United States, who have been pressing for higher tariffs to protect their home market against low-cost lead and zinc from Mexico, Canada, Australia and Peru. The Tariff Commission in fact recommended such an increase, but the President was not convinced that an increase in tariffs would benefit lead and zinc mining in the United States. It was, however, likely to depress the world market for these metals. His solution is therefore a happy one for all – except possibly the United States taxpayer.

The stability of the lead and zinc markets may be further improved as a result of the conference which the Secretary of State, Mr. John Foster Dulles, has been instructed to initiate with the representatives of foreign lead and zinc producing countries. These are intended partly to secure agreement that foreign producers will not seek to take unfair advantage of the United States stockpiling programme.

★ ★ ★

CO-ORDINATED RESEARCH

One of the advantages possessed by the larger companies and combines is that any research work they carry out can be made available to a very wide range of applications without any external marketing. An example of this is the research now being carried out by the General Electric Company on semi-conducting materials, a description of which appears on page 312 of this issue. In these new laboratories at Wembley work can be co-ordinated so that any article produced will conform directly to the requirements of some section of the company, for in the laboratories are representatives from each field of activity. Thus, as the fundamental work proceeds, each representative can take note of what may be of use to his particular section, and can make suggestions for the later development of actual devices.

In order to achieve this in practice, those responsible for the research have to work as a team, the heads of each section meeting together as the work proceeds. In this way, the direction of development can be controlled and made to follow the paths which seem likely to give the best results. An example of directed work has been in the development of guided missiles. Here, exchange of information between the departments concerned enabled the devices to be produced in the required form and with the required characteristics for those missiles which are also being manufactured by the Company. In order to compete with America, where the number of trained men available is so much greater than in this country, it is essential that effort should be co-ordinated, and that those who are available should be used in the best way possible.

★ ★ ★

SHIP REPAIRING

In a Weekly Survey note on tramp shipping (ENGINEERING, August 27) we drew attention to the fact that because of unremunerative freight rates many shipowners were no longer able to maintain their vessels properly. The annual report of C. H. Bailey, Limited, shows the impact of this on the ship repairers. The trading profit of £110,000 for the current financial year is £75,000 lower than last year and the chairman, Group Captain C. H. Bailey, in his statement for the shareholders' meeting declares that the prospects for ship repairing are now less bright than they were a year ago. The company's yards have had several periods of temporary inactivity which " seem likely to continue unless there is some favourable change in the freight market."

Foreign competition has intensified the difficulties of ship repairers. Continental yards have frequently been quoting lower prices and faster delivery and have thus attracted business even from British shipowners. Lower wage rates give the continental yards an important advantage, although the recent pressure for higher rates may diminish this so far as the German yards are concerned. Another reason for the Continental success lies in the fact that they commonly work a multiple shift system. Productivity in the British yards, on the other hand, is hampered by the complicated system of conventions (some of them anachronistic) which has grown up to govern the employment of labour. In particular there is considerable scope for rationalising the " demarkation " lines of the 39 unions in the industry.

Restrictive practices and the single-shift system necessarily prevent ship repairers from making the most effective use of expensive modern plant, and thus discourage capital investment. Since the war, however, large sums have been spent in increasing the size of docks and improving facilities. C. H. Bailey, Limited, for example, have installed new cranes at Barry dry dock, and are developing a repair berth at Newport which, when completed, " will make it one of the best equipped and most modern repair berths in the district." Outlay of this sort in spite of present difficulties shows a creditable degree of confidence in the long-term outlook for the industry, British shipping and world trade.

★ ★ ★

EASIER TRADE WITH RUSSIA

The United States Battle Act, which controls exports of strategic items to the Soviet bloc, has been adjusted to bring the restrictions into line with the decisions made recently by the Paris Committee of N.A.T.O. and Allied countries. The changes introduced reduce the list of embargo items from 297 to 217, although several of the freed items will continue to be watched or subject to quantity control. On the other hand, there have been additions to the list, including plant and equipment required for the production of titanium and of certain new plastic materials.

Among items removed from the embargo list are metal-working machine tools that are known to be in large-scale production in Russia, including lathes and smaller sizes of boring and turning mills. Smaller sizes of electric motors, generators, and Diesel engines are also freed. Some transport equipment has been freed but will be subject to quantitative control; this includes railway wagons, rails, certain types of ships and all tractors except one specialised type of heavy tractor. A few types of precision instruments have also been freed, including absorption meters, micro-hardness testers and oscillographs.

This relaxation of restrictions on East-West trade, which does not apply to trade with China, comes at an opportune moment, just before the Leipzig Fair, which is being attended by a large number of British engineering companies. It is reported from New York that another conference, to " develop trade," will be held at Geneva during October between the Soviet bloc countries and N.A.T.O. countries, including the United States, the United Kingdom and France.

★ ★ ★

HOW PERMANENT THE BOOM IN CARS?

Output of cars during the first seven months of the year was 28 per cent. above last year's level during the same period, which was itself a record. In fact, the industry produced more cars in the first half of this year than in any whole year pre-war except 1937, when output totalled 390,000 cars, a monthly average of 32,500 compared with 63,160 so far this year. The industry's performance in respect of light vans is comparable: output of vans of less than 15 cwt. load capacity in the first seven months of this year was over 13 per cent. higher than last year, and the highest since the war. There has thus been a considerable expansion of car capacity (light vans have car chassis), and it is perhaps opportune, at the height of a boom, to consider the mainsprings of demand. The industry has been taken by surprise by the rapidity of the recovery from the 1951-52 recession, as it was by the suddenness of the recession itself.

The recession had its roots in weaknesses that developed in the main export markets. In 1950 some 400,000 cars and chassis were exported – well over three-quarters of total output. More than two-thirds of exports were to five principal markets: Australia, New Zealand, Scandinavia, Canada and South Africa. Currency crises affecting four of these markets led to the introduction of import controls which cut down exports to 369,000 in 1951, 310,000 in 1952 and 302,000 in 1953. There was no fall in home sales – on the contrary, new car registrations rose by 2 per cent. in 1951, by 38 per cent. in 1952 and by 58 per cent. to nearly 300,000, in 1953. The present situation differs in two main respects: home sales at an annual rate of 370,000 during the first seven months of the year are now almost as important as exports, which were at the rate of 390,000. The export proportion has thus been reduced from 77 per cent. in 1950 to 51 per cent., although exports have never been higher. The other important difference is that the ratio of small cars (1,600 c.c. and under) to total production has much increased, from about two-thirds in 1950 to nearly three-quarters during January to July

this year. The industry has decided that demand, and particularly the long-term potential, lies in cars of less than one litre capacity. Of the "Big Five" only Vauxhall so far make no small car, and they are unlikely to remain in this position for long.

What of the future? The home demand appears to be insatiable, and the industry seems determined to sell small cars in such numbers that some time soon the only way to travel at an average speed exceeding 20 m.p.h. will be by train or by air. The roads, and to a lesser extent the purchase tax, would appear to be the only deterrents to higher home sales. Abroad, the prospects are less brilliant, though only in degree. A very high proportion of exports are still to the four markets where demand is vitally affected by fluctuations in trade and in prices of commodities. One of them, Canada, has already shown signs of weakness for this and currency reasons. Australian sales hang to a dangerous extent on the price of wool for the new season which started this week. In that market, competition from local manufacture is increasing. The Holden car has raised its share of the market steadily, from 22 per cent. in 1952 to 32 per cent. in 1953 (helped by import restrictions) and the trend is being maintained. A recognition of this is the British Motor Corporation's decision announced last week to start local manufacture on a large scale.

★ ★ ★

OPPORTUNITY IN WEST AFRICA

Construction of Tema Harbour, which is an important part of the hydro-electric and alumina development scheme in the Gold Coast, is due to be started this year and is expected to be completed in 1958. This announcement was made by Dr. Nkrumah, the Gold Coast Prime Minister, when addressing the Trans Volta Togoland Regional Council last week. Togoland is the mandated territory lying along the eastern frontier of the Gold Coast, half the mandate being under British suzerainty and the rest under the French. Neither the alumina works nor the hydro-electric scheme are in Togoland but the latter is close enough to have an important effect on the economic development of the mandate. Two other important civil engineering projects were also announced. The first of these is the bridging of the River Volta at Adomi, which should improve the coastal road from the Gold Coast to French Dahomy and hence to Nigeria. The Adomi project involves the building of a single span of 840 ft. and tenders are being invited from international firms. It is expected that the contract will be awarded by the end of this year and that the bridge will be open early in 1956. The other scheme is the eastern highway running through Senchi, almost due north to Bawku. Both Senchi and Bawku are actually in the Gold Coast but the highway will travel for most of its length through Togoland and will bring the northern area of the mandate into communication by trunk road with the coastal area of the Gold Coast.

These developments will clearly open up the country and also bind it closer to the Gold Coast. Development in this area is in fact the result of a complex of political and economic considerations. The Gold Coast is obviously anxious to bind Togoland closer to it by as many ties as possible, and the Ewes, who inhabit the southern portion of the mandate and are among the most intelligent and industrious tribes in that part of West Africa, are clearly in a position to push their claims for an adequate share of the Gold Coast's development funds as the price for not pressing their claims for a united Togoland (a subject on which the French are notably sensitive) at the United Nations. There is one general point of significance, however, apart from the complexities of the Togoland political situation. West Africa is enjoying high prices for its produce, notably for cocoa, and it is certain that as long as these high prices continue there will be a large market for engineering consultants' services and for engineering equipment in the British West African territories. Economic prosperity and rapid but constitutional political development are combining to provide unique opportunities for British engineering interests in that part of the world.

★ ★ ★

WORKS TRANSPORT

Whatever the size of a works, there is usually a problem relating to the reception of materials and supplies, their conveyance through the processing shops and the final discharge of the end products. The problem as it is met in iron and steel works was recently the subject of a two-day symposium entitled "Works Transport," organised by the British Iron and Steel Association and reported at considerable length on pages 273 to 277 of last week's issue and in a concluding article commencing on page 300 this week. The topics discussed, however, were of far wider interest than their immediate relationship to iron and steel works: they concerned equally any large organisation taking delivery and then dispatching bulk materials by road and rail.

The symposium was comprehensive: broad organisation and the appointment of traffic managers, integration with national transport facilities, design and layout of sidings and reception areas, selection of vehicles and their planned maintenance, the relative merits of road and rail transport within works and of Diesel-driven and steam locomotives, the use of very-high-frequency radio for controlling the effective operation of vehicles over relatively small areas. Although considerable data in respect of the costs of particular transport problems seemed to be available, several of the speakers pointed out that overall figures for the costs of various forms of internal transport were not available and that it was not yet possible to select a solution of a new transport problem on the basis of combined capital and full-operating costs.

★ ★ ★

POWER AND PAPER MAKING

The arrangements for the supply of the necessary power are an interesting technical feature of the large paper mill which the Bowater Paper Corporation has recently started at Calhoun in Tennessee. All the plant is electrically driven, and the demand amounts to no less than 37 MW, of which 20 MW is supplied from plant installed in the works itself, As will be gathered from the description published in this issue, this generating plant is supplied by steam from four boilers, which also provide the process steam required in the actual manufacture of the paper, and are operated by unusual methods. The two larger boilers are fired by natural gas, which is obtainable in the neighbourhood, with oil as an alternative, while provision has also been made for the use of pulverised coal. One of the other boilers is arranged for firing either by the wood bark which is removed from the logs that provide the raw material, or by natural gas, while the fuel for the fourth consists of the dry solids recovered from the various chemical processes which form part of the paper manufacture. The calorific values, both of the bark and of these solids, are naturally low and as the plant has only been in operation for a short time it is too early to assess the results. We understand, however, that the thermal efficiency is satisfactorily high and the whole arrangement shows a laudable endeavour to obtain economy in operation. The combustion of the solid waste is not unattended by difficulties and it has, in fact, been necessary to install complete dust-collecting and soot-blowing equipment. Apart, therefore, from the fact that the mill is an excellent example of British enterprise in an important field, it should provide interesting information regarding the utilisation of waste material for steam raising.

★ ★ ★

CUTTING TOOLS

Several of the large machine-tool manufacturers were able to increase their profits for the year 1953, compared with 1952. Wickman, Limited, sustained a fall of 9 per cent. in their trading profit but the net profit was very little changed on the year. Since the end of 1953, the machine-tool industry has been looking forward to increased business resulting from the investment allowance introduced in the Finance Act of 1954, but it may yet be found that the general improvement in business conditions in the last six months has given the industry a bigger stimulus than the investment allowance. For instance it is not at all clear that the allowance will not hinder sales in the second-hand market, and conditions in that market must eventually work themselves out in the market for new machines. So far as Wickman's are concerned, the chairman (Sir Stanley Rawson) makes the interesting point in his review that although the rate of incoming orders is less, there seems to be a growing interest in high-productivity machines which is increasing the value per order received. There are good reports also of the company's first deliveries of multi-spindle automatic machines.

Wickman's have a large interest in hard metal cutting tools and it is known that the more recent stable conditions in the tungsten market and the working-off of stocks by users of such tools are likely to bring more stable conditions for the manufacturers, who have been faced in the past with high and unstable raw-material costs and a somewhat fickle demand. Companies interested in hard metal tools have always insisted that turnover can only be expanded as the more conservative machine-tool users accept the potentialities of hard metals in this field. They have been hampered, too, by the large quantity of obsolescent machine tools in use until comparatively recently. The prospect for carbide-tipped tools however, is bright. Reference was made in the issue of ENGINEERING for August 20 (page 255) to the development of helical carbide-tipped cutters in this country; there are reports from the United States of collaboration between the Cone Automatic Machine Co., Inc., and the Carboloy Department of the General Electric Company of America, to develop the use of carbide cutting tools on automatic bar machines. Three automatic machines were recently tried out and the speed of the spindles was increased from about 125 r.p.m. to about 1,586 r.p.m. It is claimed that for most of these operations a new carbide has been used which is particularly suitable for continuous high-speed work.

Although the newer developments may take time to win general application among machine-tool users, just as the established uses of hard metals in tools have taken time to win a wide acceptance, the contrast between the performance offered and that of high-speed steels in given circumstances (a qualification which is important) is so marked that at worst their progressive application is likely to prove the inevitability of gradualness.

CONTRACTS

Tin-Plate Annealing Line. An order to the value of £4 million has been placed by the Incandescent Heat Co., Ltd., with DAVEY-UNITED, Park Iron Works, Sheffield, 4, for the supply of the mechanical equipment required for a continuous tin-plate strip annealing line. The plant, which will be the first of its type in Europe, is for the Velindre Works of the Steel Company of Wales.

Diesel Engines. Two orders amounting to nearly £500,000 have been received from the Argentine by F. PERKINS, LTD., Peterborough, for Diesel engines for use in goods and passenger vehicles. Empresa Nacional de Transportes has ordered 350 P6 (V) engines and spares, to the value of £250,000, for use in omnibuses in the city of Buenos Aires. The second order, also of £250,000, for 300 P6 (V) and 100 R6 (V) Diesel engines and spares has been placed by the Asociacion Argentina de Empresarios del Transporte Automotor.

Viscount Air Liners. An announcement by VICKERS-ARMSTRONG LTD., Broadway, Westminster, London, S.W.1, states that Trans-Canada Air Lines, which already has 15 Viscounts on order, has decided to place a further order for three more Viscounts and has taken an option on four more. The seven air liners, with initial spares, are valued at £2 million. The first three will be delivered during March, 1956, and the other four will be due for delivery in March, 1957. The company have also announced that Airwork, Ltd., have placed an order for three Viscount 700D propeller-turbine airliners; the aircraft are due for delivery during the first half of 1956. The 700D is a more powerful version of the Viscount, being fitted with four Rolls-Royce Dart R.DA.6 Mark 510 engines each developing 1,550 s.h.p. at take-off instead of 1,400 s.h.p. of the earlier models. Maximum take-off weight in the 700D is raised from 58,500 lb. to 60,000 lb. and the maximum fuel capacity from 1,[illegible] allons to 1,950 gallons.

Diesel Engines. The [illegible]AL GAS AND OIL ENGINE CO., LTD., Ashton-under-Lyne, have received the following orders: from Millen Bros., Ltd., Paisley, for three M4AM8-type 207-s.h.p. 1,000 r.p.m. propulsion engines for equipping motor launches; for the Benghazi power station, a B4AU5-type turbo-charged engine of 1,250 b.h.p. at 333 r.p.m. for driving an alternator; an F4AU8-type 1,040-b.h.p. engine coupled to a Brush 685-kW alternator for the Crown Agents for the Colonies for Taiping, Malaya; from John G. Kincaid & Co., Greenock, for an R4A3-type marine auxiliary set for the Lyle Shipping Co.; from British Oil Engines (S.A.), Brussels, for two M4A8-type 220-b.h.p. engines for travelling cranes being built by Titan Aneursois, Hoboken; and, from Consolidated Pneumatic Tools, Ltd., an order for two M4AA5-type 165-b.h.p. engines to drive large compressors.

Electrical Equipment for Steelworks. The GENERAL ELECTRIC CO., LTD., Magnet House, Kingsway, London, W.C.2, have obtained a contract for electrical plant, valued at £238,000, for the Ebbw Vale Steelworks of Richard Thomas and Baldwins, Ltd. The order comprises two 3,000-h.p. and one 750-h.p. twin-armature direct-current motors, a six-machine motor-generator set driven by a 9,000-h.p. 11-kV synchronous motor and all the associated switchgear and control gear embodying G.E.C.-type control exciters. At the steelworks, a three-stand tandem cold mill is to be converted into a four-stand mill and the new electrical equipment replaces that installed by G.E.C. in 1938.

★ ★ ★

We regret that corrections are necessary to the article on "Re-conditioning of Tube Lifts," on page 51 of our issue of July 9, 1954. In the second paragraph the third sentence should read "the car [not cars] and landing gate operating equipment are also to be replaced." In the second sentence of the seventh paragraph the speed has been increased from 180 ft. (not 80 ft.) to 200 ft. per minute.

In the third paragraph it should have been made clear that the reason why the full speed range of the motors cannot be used at the moment is that the speed of the existing worm gears cannot be increased beyond a certain point without excessive wear. In the fifth paragraph it should have been emphasised that it is the auxiliary power supply which is available at $33\frac{1}{3}$ or 50 cycles, the circuits being operated at 220 volts through rectifiers. The motors are supplied from the traction circuits at 600 volts.

PERSONAL

MR. KELVIN TALLENT SPENCER, C.B.E., M.C., B.Sc.(Eng.), F.R.Ae.S., A.M.I.C.E., has been appointed by the Minister of Fuel and Power to be Chief Scientist to the Ministry, in succession to Sir Harold Roxbee Cox, Ph.D., D.I.C., B.Sc., M.I.Mech.E. Mr. Spencer, who is 56, joined the Ministry in 1950 as deputy chief, under Sir Harold, of the Scientific Division that had been set up in 1948.

DR. W. H. PENLEY, A.M.I.E.E., has been promoted to the rank of deputy chief scientific officer to the Ministry of Supply and has been appointed Senior Superintendent, Guided Weapons, Radar Research Establishment, Malvern. For the past four years he has been Superintendent of Air Defence Radar.

CAPTAIN (E) P. D. OLIVER, C.B.E., R.N.(Ret.), has been appointed liaison officer for Short Brothers and Harland, Ltd., Queen's Island, Belfast, to H.M. Services and to the fighting services of friendly powers equipped with aircraft of Short design or manufacture. During his service in the Royal Navy, Captain Oliver specialised in engineering and became a pilot in the Fleet Air Arm in 1925.

REAR-ADMIRAL SIR PHILIP CLARKE, K.B.E., C.B., D.S.O., has been elected President of the British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1, for the 1954-55 session. He has been a vice-president of the Institution since 1952.

MR. J. W. CAMPBELL, chief accountant and assistant secretary of Stewarts and Lloyds Ltd., who was seconded to the Iron and Steel Corporation as financial adviser in 1951, and retained in that position by its successor, the Iron and Steel Agency, has been released by the company, at the Agency's request, from his appointment as chief accountant. He will continue as financial adviser to the Agency. MR. W. L. JOLLIE, chief accountant and assistant secretary of the Stanton Ironworks Co. Ltd., has been appointed chief accountant of Stewarts and Lloyds Ltd. and of all their subsidiaries in the United Kingdom. He has ceased to be an assistant secretary of the Stanton Co.

MR. S. E. H. KEWNEY, A.M.I.Mech.E., assistant to the managing director of Andrew Barclay, Sons & Co., Ltd., Caledonia Works, Kilmarnock, has been appointed a director and general manager to the company.

MR. E. M. JUBB, B.Sc., has been awarded the Aluminium Development Association Research Scholarship in the use of light alloys in structural engineering, for the year 1954, by the Council of the Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1.

MR. G. H. PASSEY, previously assistant engineer (rail cars) for A.E.C. Ltd., Southall, Middlesex, has been appointed Diesel traction engineer to British United Traction Ltd., Leyland, Lancashire. He will be responsible for the design and development of B.U.T. Diesel trains and associated equipment, and for the management of the company's drawing office at Boreham Wood. MR. F. HODGKINSON, previously a technical assistant with A.E.C. Ltd., has been appointed to the company's engineering department at Boreham Wood.

MR. CHARLES WATSON, for many years chief sales engineer to British Ermeto Corporation Ltd., Hargrave-road, Maidenhead, has been appointed a director of the company.

MR. E. H. JERRETT, general manager, the Cambrian Wagon and Engineering Co. Ltd., Maindy, Cardiff, has been appointed a director of the company.

POWERS-SAMAS ACCOUNTING MACHINES LTD., 5-11 Holborn, London, E.C.1, announce that negotiations to enable them to take over additional production capacity from Vickers-Armstrongs Ltd. are now in an advanced stage. MR. ROBERT WONFOR has been appointed managing director for sales, finance and research, and MR. T. R. SWIFT managing director for production. MR. F. G. S. ENGLISH, previously in charge of production, has been appointed production-control adviser and managing director of Powers-Samas Developments Ltd., a wholly-owned subsidiary. His office will be at 88 High Holborn, London, W.C.1. Mr. Wonfor has been appointed chairman of Powers-Samas Developments Ltd. and MR. F. J. NASH an additional director.

★ ★ ★

BUSINESS CHANGES

METALLISATION, LTD., Barclays Bank Chambers, Dudley, Worcestershire, have been appointed by VACU-BLAST LTD., 8 Basinghall-street, London, E.C.2, to be their agents for the distribution and servicing of machinery and auxiliary equipment in the counties of Nottingham, Derby, Lincoln, Leicester, Rutland, Northampton, Stafford, Shropshire, Worcester, Warwick, Merioneth, Montgomery, Cardigan, Radnor, and Hereford.

The FRASER AND CHALMERS ENGINEERING WORKS, Erith, of the GENERAL ELECTRIC CO., LTD., have concluded an agreement with the HUMPHREYS INVESTMENT CO., Denver, Colorado, U.S.A., to become the agent respecting the sales of Humphreys' spiral concentrators for delivery to the United Kingdom, Gold Coast, Gambia, Sierra Leone, Nigeria, Burma, India and Pakistan.

Construction has commenced on a new factory at Poole, Dorset, for the HAMWORTHY ENGINEERING CO., LTD., Poole, and its wholly-owned subsidiary, BRITISH COMBUSTION EQUIPMENT, LTD. The new factory is expected to come into operation towards the end of the year, but the parent organisation are also retaining their present premises.

FINNEY PRESSES LTD., Berkley-street, Birmingham, 1, have been appointed sole selling agents for the range of forming, bending and straightening oil hydraulic presses manufactured by Hollmann-Werke G.m.b.H., Wetzlar, Germany.

BRITISH INSULATED CALLENDER'S CABLES LTD., Norfolk House, Norfolk-street, London, W.C.2, and W. T. GLOVER & CO. LTD., Trafford Park, Manchester, 17, have formed a company, to be known as BRITISH INSULATED CALLENDER'S (SUBMARINE CABLES) LTD., which will specialise in the design and manufacture of submarine power cables. The registered office of the new company, which will have an authorised capital of £250,000, will be at Norfolk House and the works at Trafford Park. MR. W. H. MCFADZEAN, C.A., has been appointed chairman of the company; the other directors being MR. C. O. BOYSE, B.Sc.(Eng.), M.I.C.E., M.I.E.E., MR. K. S. BRAZIER, B.Sc.(Eng.), M.I.E.E., M.I.Mech.E., MR. E. L. DAVEY, B.Sc.(Eng.), M.I.E.E., MR. R. M. FAIRFIELD, B.Sc.(Eng.), M.I.E.E., M.I.Mech.E., MR. W. C. HANDLEY, B.Sc.(Tech.), M.I.E.E., MR. D. T. HOLLINGSWORTH, M.I.E.E., and MR. H. J. STONE, M.C., M.I.E.E.

DAVEY, PAXMAN & CO. LTD., Colchester, have moved their London office to 1 Balfour-place, Mount-street, W.1. (Telephone: GROsvenor 6114-5.) The manager of the London office is MR. A. C. PARKER.

MR. JOHN LUND has terminated the manufacturing arrangements for the "Hydro-Tracer" profiling and copying valve which he had with HAYES ENGINEERING (LEEDS) LTD., and has joined the Machine Tool Division of FAIRBAIRN LAWSON COMBE BARBOUR LTD., Leeds 1, to whom he has delegated all patent rights in the valve.

A. GUNN & CO. LTD., Bold-street works, Altrincham, Cheshire, have been appointed by ARPIC ENGINEERING LTD., makers of air compressors, Queenslie Estate, Glasgow, E.3, to be sole agents for Arpic products in Lancashire, South Cheshire, Derbyshire, and the West Riding of Yorkshire.

★ ★ ★

OBITUARY

We regret to announce the deaths of the following:

SIR HENRY STEWARD, T.D., at his home in London on August 28, at the age of 89. Sir Henry, who was a barrister of the Inner Temple, was vice-president of the City and Guilds of London Institute in 1950, a vice-president of the Royal Society of Arts from 1938 to 1942, President of the Union of Educational Institutions from 1938 to 1943, and of the Association of Technical Institutions from 1939 to 1943.

MR. CHARLES ALBERT SPENCE, chief service engineer of Dewrance and Company, Limited, London, after a short illness, on August 19, at the age of 54. He had been in the firm's service for nearly fifteen years.

MR. EDMONDS FRANK MACTAGGART, B.Sc., A.R.C.S., M.I.Chem.E., of Angra House, St. Peter, Jersey, on August 27, at the age of 49. Mr. Mactaggart formerly resided at Dorking, Surrey.

MR. FREDERICK WILLIAM WOODFIELD, B.Sc. (Manch.), A.M.I.Mech.E., M.Inst.F., manager of the Manchester office of Babcock and Wilcox, Limited, on August 23, at the age of 60. He was a member and past-chairman of the technical advisory committee for the Fuel Efficiency Exhibition, and an active member of the Engineers' Club, Manchester. He joined the staff of Babcock and Wilcox in 1929 and was appointed to the Manchester office in 1935. For many years, he was a director of Erith's Engineering Co., Ltd., one of Babcock's subsidiary organisations.

Letters to the Editor

MOLYBDENUM DISULPHIDE

Comparison with Graphite as a Lubricant

SIR, I have read with interest Mr. F. Gordon Kay's letter published in your issue dated August 20, and I feel certain that no reflection on the value of graphite was intended in the brief account of the use of molybdenum disulphide as a lubricant for extreme pressures and temperatures which appeared in the issue of August 6.

Mr. Kay is, of course, quite right in saying that graphite has been employed for a much longer period than molybdenum disulphide, and its characteristics as a lubricant are well established. While the lubricating characteristics of molybdenum disulphide have also been known for many years, it is only comparatively recently that it has become available in a pure refined form and processed in half a dozen or more carriers. It has thus been made suitable for putting on to metal surfaces a lubricating skin which can be relied on to prevent metal to metal contact under severe conditions and over considerable periods of time.

Having had experience of some hundreds of practical lubricating problems in engineering works, I feel that it is fair to say that it is mainly those with problems hitherto unsolved by conventional lubricants who have as yet turned to molybdenum disulphide.

The reference in the article to the building up of a " thick " layer of graphite will have alluded to a graphite scale not under pressure; by unskilful and too liberal application, the graphite is at times allowed to build up, thereby defeating its object and causing mechanical clogging.

Perhaps owing to its greater cost, molybdenum disulphide does not normally suffer from wrong use of this character. In any case, the best results are obtained by the sparing application of only enough to form a homogeneous film on the metal surfaces. The need of replenishment arises but infrequently.

The difference in performance between graphite and molybdenum disulphide under certain operating conditions has been investigated by, among others, Professor G. Spengler of Munich.* Although their laminar crystal structure is similar, to remain effective as a lubricant, graphite is stated to be dependent on an adsorbed film of moisture on the laminæ faces, while the lubricating characteristics of molybdenum disulphide have been found to be independent of adsorption films. This appears to be well borne out by the good results obtained with molybdenum disulphide under operating conditions which do not allow moisture films to form on the cleavage faces or where they are impaired, e.g., in dry atmospheres resulting from vacuum or other conditions. Its success under very high pressure, particularly where local heating occurs, may also be attributable thereto.

Surely the scope for either material is more than sufficient in the host of problems for which one or the other is suitable. The contribution which Mr. Kay's firm is making towards their solution is as welcome as we trust ours to be.

Yours faithfully,
H. R. GOLDIE,
K. S. Paul, Limited.

Great Western Trading Estate,
Park Royal-road,
London. N.W.10

* *V.D.I.* (*Zeitschrift des Vereines Deutscher Ingenieure*), June 11, 1954, pages 506-612 and July 11, 1954, pages 683-687.

HIRAM MAXIM

SIR, I was secretary to the late Hiram Maxim from 1899 until his serious illness in 1902. I worked in London and was at that time Miss Yorke. Now, with the idea of writing my own story, I am trying to collect accurate and relevant data about various well-known men for whom, in the course of a long and busy life, I have done similar work. I would therefore be grateful to any of your readers who have recollections of Maxim, or who could lend me copies (which would be carefully returned) of correspondence with him.

Yours faithfully
L. M. CARGILL (Mrs.).

29 Vicarage Walk,
Seaford,
Essex.

★ ★ ★

HEAT CAPACITY OF LAMINATIONS

SIR, It is very kind of Dr. Marks and his firm to offer this Department samples of transformer sheet with the latest surface coatings and we shall be happy to accept the offer.

In his last letter, on page 167 of your issue of August 6, Dr. Marks discussed thermal conductivity more than thermal capacity. It will undoubtedly be true that the radial conductivity will greatly exceed the axial conductivity, but one would expect the latter to be affected significantly by the axial packing pressure as well as by surface finish and insulation. Perhaps both thermal conductivity and thermal capacity are now best regarded (for a time) as *sub judice* while measurements are made.

Yours faithfully,
L. G. A. SIMS.

Electrical Engineering Department,
Southampton University.
August 24, 1954.

★ ★ ★

GAS-TURBINE CAR WITH HEAT EXCHANGER

Successful Austin Tests

Successful tests have been made recently on an Austin Sheerline saloon fitted with a gas turbine capable of developing 125 h.p. To keep the fuel consumption down, a heat exchanger, which enables additional energy to be extracted from the hot exhaust gases, has been incorporated. With the exception of the Chrysler engine developed in the United States, about which little has been published, this is believed to be the first successful application of a heat exchanger to a gas turbine in a motor vehicle.

The results obtained so far are said to be so encouraging that research work is to be intensified, but more than this the company have declined to say. The technical details given state that a two-stage compressor driven by a three-stage compressor turbine followed by a separate power turbine and cross-flow heat exchanger have been used.

The design work was carried out in the research laboratories of the British Motor Corporation (the joint Austin-Morris concern) and this announcement was made by the Austin Motor Company, Limited, Longbridge, Birmingham.

★ ★ ★

SELF-SERVICE IN A WORKS STORES

Savings in Space and Clerical Work

The Lockheed Aircraft Company, Marietta, Georgia, U.S.A., have introduced a system of self-service in their material-issuing stores. It is based upon the principle used in the American "supermarkets" and is similar to that used by many restaurants and stores in this country.

The main feature of this scheme is that the stores are now open to the worker, who accepts the responsibility for collecting the parts he requires. The bins and racks are within a few feet of the places where the men are working on assembly.

This system does away with the use of requisitions and tallies normally presented to the storekeeper. As a result, about 25 per cent. less personnel are now employed in the material-issuing department and 60,000 sq. ft. of floor space has been saved. The annual cash savings have been estimated as 250,000 dols. and the company propose to extend the system to their other plants.

★ ★ ★

INSTITUTION OF CIVIL ENGINEERS AWARDS

Graduates' and Students' papers

The Council of the Institution of Civil Engineers have announced the following awards have been made for graduates' and students' papers read in session 1953–54, before the Association of London Graduates and Students, and Local Associations: –

The James Forrest Medal, the James Prescott Joule Medal, and a Miller Prize to D. H. Kent (former Stud. I.C.E.) for his paper " Models of Hydraulic Structures " (Association of London Graduates and Students).

Miller Prizes to: – B. N. Harvey, Grad.I.C.E., for his paper " Concrete work at Upper Glendevon Reservoir " (Edinburgh and East of Scotland Association); R. W. Rennison, Grad.I.C.E., for his paper " The Design and Construction of Rapid Gravity Filters " (Northern Counties Association); R. W. Drummond, Stud.I.C.E., for his paper " The Use of a Climbing Shutter on Luichart Surge Shaft " (Edinburgh and East of Scotland Association); B. A. M. Watt, Stud.I.C.E., for his paper " Construction of Retaining Wall " (Glasgow and West of Scotland Association); N. S. Lindsay, Grad.I.C.E., for his paper " A Report on a Levelling Operation " (Glasgow and West of Scotland Association); J. D. Addly, Grad.I.C.E., for his paper " Construction of Water Supply Works by Direct Labour in Dumfriesshire " (Edinburgh and East of Scotland Association); G. E. Peart, Grad. I.C.E., for his paper " Modern Methods of Permanent Way Maintenance and Renewal " (South-Western Association); William Sommerville, Stud.I.C.E., for his paper " Stream Intakes " (Glasgow and West of Scotland Association).

★ ★ ★

HYDRO-ELECTRIC WORK IN IN SCOTLAND

Scheme for Isle of Harris

The North of Scotland Hydro-Electric Board have published details of their Constructional Scheme No. 35. This provides for harnessing the waters of Loch Chliostair, which has a catchment area of 2¾ square miles in the hills behind Amhuinnsuidhe on the northern shore of West Loch Tarbert, about 12 miles from Tarbert in the Isle of Harris.

The works will include a dam 260 ft. long and 30 ft. high, which will be built at the outlet of the loch, and a pipe line, 4,000 ft. long, through which water will be led to a power station on the bank of the River Eaval. This power station will have an installed capacity of 700 kW and will generate about 2·4 million kilowatt-hours per annum.

Electricity will be supplied to the Board's distribution system, which has been extended from Lewis into Harris. At present there is Diesel-engined plant, with acapacity of 3,600 kW, which generated 8·6 million kWh in 1953 at Stornoway.

AIRCRAFT INDUSTRY'S DISPLAY AT FARNBOROUGH

1—AIRCRAFT FOR RESEARCH, FLYING AND FIRING TRAINING, AND AIR-OBSERVATION

The annual display of the Society of British Aircraft Constructors is due to open at Farnborough, Hampshire, on Tuesday, September 7, following a preview for technicians on Monday, September 6. On Tuesday, Wednesday and Thursday, the display is on view only to invited guests of the Society, Thursday being devoted to civil aircraft. From Friday, September 10, to Sunday, September 12, the display is open to the public.

This year, again, there are few completely new aircraft taking part in the display. Notable exceptions are the Folland Midge lightweight fighter aircraft and the Vickers-Armstrongs 525 twin-engine experimental naval fighter. The supersonic English Electric P1 aircraft, which flew for the first time this summer will not be demonstrated, partly for security reasons and partly because it is important not to interrupt its development trials.

SB5 RESEARCH AIRCRAFT FOR SUPERSONIC P1

The SB5 research aircraft constructed by Short Brothers and Harland Limited, Belfast, will be watched with renewed interest since the recent disclosure that this aircraft, which has a variable sweep-back wing and adjustable tailplane position, has made a big contribution to the development of the supersonic P1 aircraft. In fact the latter (Fig. 1) bears a strong resemblance in configuration to the small SB5 aircraft (Fig. 2), with sharply swept-back thin wings set slightly higher than midway on the fuselage, and engines installed within a deep fuselage with a nose intake and exhaust jets emerging from the tail. The Short SB5, it may be recalled, is powered by a single Rolls-Royce Derwent 3,500-lb. thrust engine whereas the P1 has two Armstrong Siddeley Sapphire engines, of unspecified thrust, which appear from the photograph to be disposed one above the other. Last year the SB5 was seen with the wings swept back to 60 deg. and the tailplane set at the top of the fin. This year it will be flown with the tailplane in a low position, still with 60-deg. swept-back wings. Later this year, the sweep-back will be increased to the maximum, 69 deg.

JET PROVOST TRAINING AIRCRAFT

Among the smaller aircraft appearing in public for the first time will be the Jet Provost (Fig. 3) built by Hunting Percival Aircraft, Limited, Luton Airport, Bedfordshire. It is intended to serve both as a primary and basic flying training machine, to familiarise pilots with jet technique right from the start.

The Jet Provost, developed from the standard Leonides-powered Provost military trainer, is propelled by an Armstrong Siddeley Viper Mark 5 axial-flow jet engine developing a static thrust of 1,750 lb. It has a fuel capacity of 179 Imperial gallons (in comparison with 66 gallons for the piston-engined Provost). Provision is also made for fitting two 50-gallon wing-tip tanks. It is provided with a retractable tricycle undercarriage, pneumatically operated, the supply system being of the high-pressure type (3,300 lb. per square inch).

The principal dimensions are: span, 35 ft. 5 in.; length, 31 ft. 11 in., height, 12 ft. 8 in.; track, 10 ft. 1·4 in. The all-up weight is 5,950 lb., not carrying fuel in the tip tanks; with full tip tanks the weight is 6,750 lb. The estimated performance is as follows: maximum speed approximately 280 knots at 20,000 ft.; sea-level rate of climb, at 5,950 lb. all-up weight, approximately 2,500 ft. per minute; and at 6,750 lb., approximately 2,100 ft. per minute; the time to climb to 20,000 ft. being 11·9 minutes and 15 minutes respectively, and to 30,000 ft., 24·4 minutes at 5,950 lb. At 6,750 lb., the operational ceiling (at which the rate of climb is 400 ft. per minute) is 27,500 ft. The distance required to take off and clear a 50-ft. obstacle, at a weight of 6,750 lb., is estimated at 820 yards, the corresponding landing distance being 740 yards. At the maximum all-up weight, the estimated stalling speed with undercarriage and flaps down is 71 knots.

ARMED PROVOST AIRCRAFT

Also on view for the first time is an armed version of the piston-engined Percival Provost aircraft, which has been ordered by the air forces of Burma, Eire and Southern Rhodesia for training pilots in gunnery, bombing, etc. The side-by-side seating provided for instructor and pupil pilot is an asset in demonstrating sighting techniques. The armed Provost (Fig. 4) carries two 0·303-in. machine guns mounted in the wings and a camera gun; beneath the wings there is provision for carrying the following alternative armament: two 250-lb. bombs, eight 25-lb. bombs on light series carriers, or eight 25-lb. bombs and four 60-lb. rocket projectiles, or six 60-lb. rocket projectiles.

AUSTER AIR OBSERVATION POST

The " Air Observation Post " for military use, the A.O.P. Mark 9, constructed by Auster Aircraft, Limited, Rearsby, Leicester, is a completely new development and is not evolved from the existing civil types to which it bears a superficial family resemblance. It is shown in Fig. 5.

Although primarily intended as a two-seat observation aircraft, there is provision for installing three seats and the cabin is sufficiently spacious for ambulance duties, supply and mail dropping, aerial photography, etc. A single Perspex windscreen and a moulded Perspex top canopy and side panels ensure an excellent all-round view.

Powered by a Blackburn and General Aircraft Bombardier direct-injection engine developing 180 h.p., the A.O.P. Mark 9 has larger wings and flaps, with drooping ailerons, giving it an exceptionally high take-off performance superior to those of earlier Auster aircraft, which have always been noted for their ability to operate from small confined fields.

At an all-up weight of 2,100 lb., and in a 6-m.p.h. wind, the A.O.P. Mark 9 will take-off and clear a 50-ft. obstacle within 210 yards, requiring a ground run of 108 yards. It can land over a 50-ft. obstacle within 150 yards. The initial rate of climb is 920 ft. per minute and the absolute ceiling 18,500 ft. At economical cruising speed, the maximum still-air range is about 240 statute miles. The maximum cruising speed is 110 m.p.h. and the maximum level speed 127 m.p.h. The dimensions are as follows: wing area, 197·6 sq. ft.; span, 36 ft. 5 in.; overall length, 23 ft. 8½ in.; height, 8 ft. 11½ in.

Interesting structural features of the aircraft are the use, in conjunction with a welded steel-tube fuselage framework, of stressed Dufaylite cabin floors forming part of the main load-carrying structure – Dufaylite being a sandwich-type material in which two light-alloy skins are bonded to a honeycomb paper core. The seats, arranged for quick release, are also constructed in Dufaylite. Redux-bonded chordwise stiffeners are extensively employed in the two-spar tail

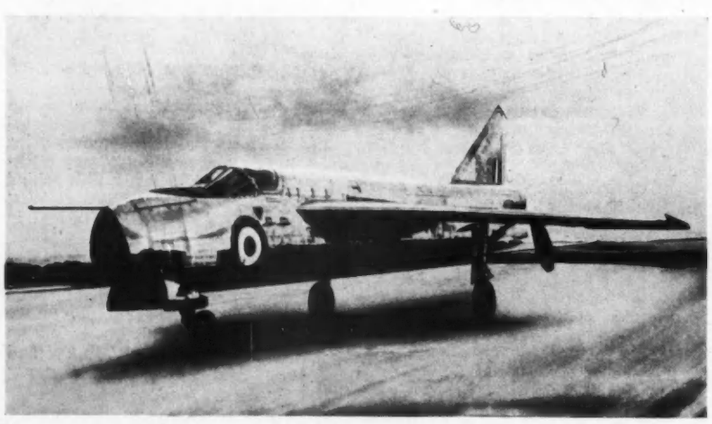


Fig. 1

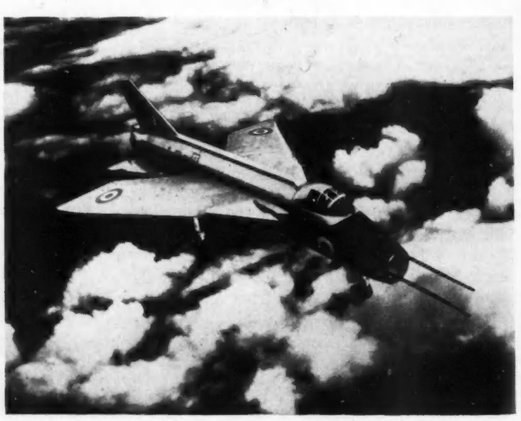


Fig. 2

Figs. 1 and 2 Although the English Electric P1 supersonic aircraft (Fig. 1) will not appear at Farnborough, some idea of its configuration can be gathered from the Short SB5 variable sweep-back research aeroplane (Fig. 2) which played a large part in its aerodynamic development.

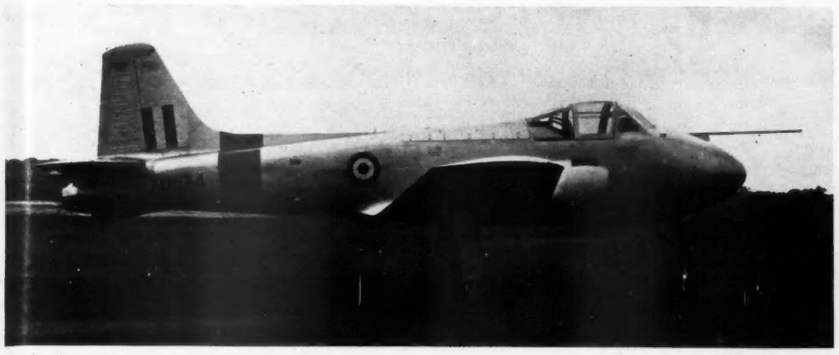


Fig. 3 The Hunting-Percival Jet Provost aircraft, for primary and basic pilot training, is powered by an Armstrong Siddeley Viper Mark 5 jet engine.

Fig. 4 The armed Provost aircraft carries two 0·303-in. machine guns and a variety of underwing offensive armament.

plane, elevators and rudder, in place of ribs, root and tip ribs only being used to maintain the aerofoil section. The leading edges of the tail surfaces are also free from ribs, being stiffened by bonded inner skins. The main-wing structure comprises a light-alloy leading-edge torsion box braced to the fuselage by single streamline-section lift struts. Aft of the spar, the cantilever ribs are covered by a doped-fabric skin. A 16-gallon self-sealing fuel tank is carried in the starboard wing root.

For landing on unprepared fields, a sturdy undercarriage is essential. Each main leg comprises a single forging with a Dowty liquid-spring shock absorber capable of withstanding a descent of 9 ft. per second. The landing loads are taken through a shock truss consisting of a box-sectioned extrusion extending across the cockpit floor between the undercarriage pick-up points. The tailwheel, also fitted with Dowty liquid spring, is fully castoring. The slotted ailerons are interconnected with the flaps so that they drop when the take-off flap is selected, giving extra lift for take-off and higher drag for steepening the landing approach.

MANUAL-HYDRAULIC POWER PACK

The self-contained manual-hydraulic power pack for assisting the flaps in the A.O.P.9, which has been developed by the Lockheed Hydraulic Brake Company, Limited, Leamington Spa, consists of a hydraulic pump, a selector valve, fluid reservoir, and a pressure-relief valve. The complete unit, including the hand lever by which the flaps are operated, weighs 4½ lb., and exerts a thrust of about 750 lb. over a distance of 2·15 in. For this output, four strokes of the jack are required, each demanding a hand load of less than 20 lb. The valve is arranged so that the flap, which can be inched down, is locked at any selected position, but can blow back under controlled conditions against overloads.

Fig. 5 The Auster A.O.P. Mark 9 air-observation post for army use has stressed floors of Dufaylite sandwich construction and employs Redux-bonded reinforcement in the tail surfaces.

Other aircraft which will be seen at Farnborough include Canberra test-beds for a more powerful version of the Armstrong-Siddeley Sapphire jet engine (the Sapphire 7), and for the Bristol Olympus engines; an Ambassador test-bed for Bristol Proteus propeller turbines and, it is believed, a Varsity aircraft serving as a test-bed for Napier Eland propeller turbines.

All the "super-priority" aircraft will take part – the Fairy Gannet, which will be shown both as the service Mark I anti-submarine and in the new T.2 trainer version; the standard Hawker Hunter F.1, now released for service, and the Armstrong-Whitworth-built Hunter F.2 powered by a Sapphire engine; the production Vickers-Armstrongs Swift F. Mark 4, and the B. Mark 2 version of the Vickers-Armstrongs Valiant; the prototype Sapphire-powered Avro Vulcan delta-wing bomber aeroplane; and a formation flight of Gloster Javelin delta-wing fighters. In addition to the Canberra flying test-beds entered by Armstrong-Siddeley Motors, Limited, and the Bristol Aeroplane Company, Limited, there will be a standard Canberra PR Mark 7 photographic reconnaissance aircraft, and a new bomber version, the B. Mark 8, for low-level night-intruder work.

The Vickers-Armstrongs Viscount airliner will be seen on Tuesday only. The de Havilland Comet 2 and 3 are expected to fly, as is also the dH 110 twin-engine all-weather fighter aircraft under development for the Royal Navy. Experimental aircraft include the Short Sherpa aircraft with aero-isoclinic wing, to be seen by the public for the first time, and the small Fairey delta-wing machine. The Westland S.55 helicopter, powered by an Alvis Leonides Major, the Bristol 173 twin-rotor helicopter, and military and civil versions of the Saunders-Roe Skeeter helicopter, will be seen. Among the well-established aircraft there will be a Hunting-Percival Pembroke communications aircraft, a de Havilland Heron airliner, a Boulton Paul Balliol trainer, and a Sea Hawk constructed by the Armstrong-Whitworth company. Some of these machines will be described in greater detail in a future issue.

To be continued

* * *

GELLING POLYVINYL CHLORIDE

Use of Radiant Heat

The "oilskins" made by the Great Grimsby Coal, Salt and Tanning Company, Limited, are now being covered with a tough and durable coating of polyvinyl chloride. This coating is obtained by spreading a paste of appropriate composition on the fabric and then solidifying, or gelling, it by the application of radiant heat.

The furnace used to apply this heat has been designed by the General Electric Company, Limited, Kingsway, London, W.C.2, and consists of sheathed wire elements with a maximum rating of 36 kW, which are mounted in reflectors of aluminium alloy. It is divided into three sections, each of which can be switched on to full or half load, thus ensuring that the coated fabric is completely and uniformly gelled when it leaves the plant. Distribution has also been arranged so that discolorisation due to local overheating is avoided.

In operation, the fabric with its covering of polyvinyl chloride is passed into the furnace from a spreader and the paste is gelled in 30 seconds. Although the plant is only three yards long, some 360 yards of material in widths up to 40 in. can be dealt with in an hour.

THE COMPILATION OF INSTRUCTION MANUALS

Educating the Semi-Skilled

As machinery increases in complexity the problem of servicing and maintaining it becomes more and more formidable. This is especially so when the machinery is to be operated by individuals without specialist knowledge of its working. Items of machinery made in large numbers and having an extensive range of applications, such as internal-combustion engines, present a particular difficulty since the plant issued by any company is likely to exceed considerably the repair and maintenance capacity of its service department. Consequently there is an increasing need for comprehensive instruction manuals and for emphasis to be placed in compiling them on form and presentation.

DIESEL ENGINES

To simplify the operation, overhaul and repair of their Diesel engines, Davey, Paxman and Company, Limited, Colchester, have introduced a series of instruction manuals and parts lists which, they believe, will enable semi-skilled men without previous technical experience to perform all the essential tasks of maintenance, and it is hoped therefore that it will seldom be necessary for the user of an engine to employ a visiting service engineer. The aim in preparing the manuals has been to provide clear and simple explanations of both the operation and assembly of the engines and a number of unusual features have been combined to achieve this result.

Both the parts lists and the instruction manuals are divided into sections under such headings as "gearbox" or "fuel system," and these are rapidly located by a convenient thumb index. Illustrations and drawings are numerous and where they refer to information given on a separate page they may be so unfolded that diagram and description can be seen together.

Moreover, in order to avoid confusion between similar engines, differing only in minor details, the manuals have been constructed on a loose-leaf system so that wherever a modification occurs a corrected leaf can be substituted for the original one. A given manual therefore will refer only to the particular engine concerned. This feature also serves to simplify the compiling of manuals for engines of various sizes and, in the present case where there are seventeen models, each built to serve several applications, the economy is a considerable one. Advantage is taken too of the existence of standard parts since a leaf describing one component may apply in a number of instances and can therefore be used repeatedly.

PARTS LISTS

The parts lists are clarified by exploded arrangement drawings which are numbered and relate to corresponding data given in columns on adjacent pages. The instruction manuals include coloured flow diagrams so that each circuit may be recognised distinctly; and no detail of operation or assembly, however fundamental, from the timing of the engine cycle to the securing of nuts, is omitted.

In this way, it is hoped, men with no other qualification than the ability to read may become capable mechanics, and engines may thus be efficiently maintained without recourse to trained service engineers. Although the ideas embodied in these manuals are not necessarily entirely new, the aim of providing simple and lucid instructions as a substitute for skilled manpower is one that might profitably be studied throughout British industry.

POSSIBLE USES OF TOWNS' WASTE

LITTLE SCOPE IN AGRICULTURE

The treatment and disposal of sewage and towns' wastes are expensive operations and any methods by which costs could be partially offset by the production of a saleable product should be attractive to sewage-works authorities. Such methods are already practised to some extent; as one example, at the Mogden Works of the West Middlesex Main Drainage Board a mixture of crude and surplus activated sludge is digested and after air-drying is disposed of as a manure. In addition, a proportion of the semi-dry sludge is heat-dried and pulverised and sold as a high-grade manure containing 3 per cent. of nitrogen. Although the provision of some income to offset sewage-works costs may be of importance, this matter is usually looked at from the point of view that the nitrogen, phosphoric acid and potash in sewage-works products, now largely running to waste, should be recovered and utilised in agriculture.

In view of the interest taken in this matter and the divergent views which are held concerning it, the Natural Resources (Technical) Committee has investigated the subject and published a report* in which both its practical and economic aspects are dealt with. This Committee, which was appointed by the Lord President of the Council in November, 1950, is concerned with the technical problems involved in the use and conservation of natural resources. This is the first of its studies the results of which have been published. The general conclusion reached is that the optimistic views sometimes expressed about the great potential agricultural value of town-waste products are not justified.

The total sewage from the population of England and Wales includes, first, the sewage from a rural population of six to seven millions; this is mostly already disposed of on the land. Secondly, that from a population of six to seven millions living on or near the coast, which is discharged directly to the sea; the installation of plant for the recovery of sludge would involve costs which could only be partly offset by the sale of sludge as manure. Of the sewage from a population of about 32 millions living inland, about 5 per cent. is not suitable for use in agriculture as it contains toxic products. The total dry sludge recoverable is 800,000 tons per year. Of this, 350,000 tons are already applied to land in various forms, 320,000 tons are stored in embankments and tips and 130,000 tons are taken by tank steamer and discharged at sea. It is considered that the maximum amount of sludge not at present used in agriculture is unlikely to exceed 400,000 tons (dry matter) per year. This would contain about 10,000 tons of nitrogen. The figure of 400,000 tons includes sludge at present transported to sea and that used in tips, and neither of these quantities could be made available to agriculture without costly plant extensions.

The figure of 10,000 tons of nitrogen may appear a useful contribution for agricultural use, but apart from the cost of recovering it, a correct perspective of its importance is only obtained by comparing it with the 210,000 tons of nitrogen contained in the agricultural fertilisers used in 1953. The report gives similar comparisons for phosphoric acid and potash. Of the former, 400,000 tons were contained in fertilisers and 40,000 tons were recoverable from towns' wastes. The figures for potash are 211,000 tons and 25,000 tons. The report is not entirely negative, and although it is shown that the extensive claims sometimes made about the potential agricultural value of sewage waste are exaggerated, it suggests that the preparation of composts of sewage sludge and agricultural wastes by local authorities in collaboration with farmers may be justified where local conditions are favourable, and that there may be a possible use for compost and heat-dried digested sludge in horticulture, the higher price of horticultural products, compared with the main farm crops, covering the cost of preparation. It is also suggested that attention might be given to the problem of recovering the nitrogen now lost in the effluent from sewage works.

* *The Use of Town's Wastes in Agriculture*. H.M. Stationery Office. (1*s*. 3*d*. net).

* * *

POLYVINYL ALCOHOL FILMS

Water Soluble but Resistant to Organic Solvents

A natural-coloured polyvinyl alcohol film, which is suitable for use when moulding and forming reinforced polyester resins, has been developed by May and Baker, Limited, Dagenham, Essex. The film, produced in two grades, "Pevalon H.11" and "Pevalon H.12," has been used as a mould-release agent, a final laying-up blanket and as a separate sheet in "rubber-bag" moulding. Pevalon, particularly the H.12 grade, is also suitable for making water-soluble bags that can be used for packing pre-dosed components of wet mixes, and for laminations to paper to provide a grease-, oil- or petrol-resistant surface.

Both grades of Pevalon absorb moisture from the atmosphere in amounts which increase with the humidity of the air. Both films have a high water-vapour transmission rate. Grade H.11 rapidly dissolves in water temperatures above 65 deg. C. and remains in solution on cooling; at lower temperatures it softens and dilates but does not readily dissolve. The other grade, however, readily dissolves in both hot and cold water. Both films are claimed to be unaffected by many organic solvents, including petroleum and greases as well as animal and vegetable fats. Among the few organic compounds which do have some solvent action, however, are glycerine, ethylene glycol, some amides and amines. The physical properties (such as tensile strength, maximum elongation and shear strength) all vary with relative humidity.

Pevalon may be joined to itself, or to paper, with "Pevafix" adhesive. The best method of applying this liquid adhesive is by feeding it from a wick, when the flow can be regulated. Joints which are likely to be severely stressed in use may be improved by moderate heat treatment with a heat-sealing machine or an electric soldering iron. The edges to be joined must be free from oil or grease and care should be taken that neither insufficient nor excessive adhesive is applied. Sealing can be effected by heat alone, though the treatment necessary for this depends upon moisture conditions.

Polyvinyl alcohol is not toxic to animals when administered by mouth or applied to the skin. It is recommended, however, that careful tests should be carried out to determine any effects on flavour or wholesomeness when it is proposed to use Pevalon films in direct contact with foods.

Book Reviews

TRIBUTE TO A GREAT PHYSICIST

Rutherford by Those Who Knew Him. Being the Collection of the First Five Rutherford Lectures of the Physical Society. *The Physical Society, 1 Lowther-gardens, London, S.W.7.* (8*s.* 6*d.*; 5*s.* to Members.)

Almost the last words in this welcome collection of tributes to the memory of Lord Rutherford serve as a fitting final appraisement of the man. They are contributed by Dr. A. S. Russell, who records that Rutherford often said, in his modest way, that scientific advances depended on the work of many men engaged on the same problem. This is frequently regarded as applicable to scientific research which, it is considered, can now only be carried on by teams; the complexity of modern problems is thought to be such that they can no longer be investigated by lonely Faradays. Dr. Russell questions this and suggests that " it is nearer the mark to say that the more fundamental the science the greater is the need of the big advances which only great men can make. At the least they save us years of waiting while the team of talented workers . . . make their belated discovery."

Rutherford certainly worked with teams, except perhaps during the 1914-1918 war, when he, in such time as he could spare from Government work, and with the assistance only of Kay, the steward of the Manchester laboratory, succeeded in showing that the nitrogen nucleus could be disrupted by the impact of a swift α-particle with the emission of a hydrogen nucleus. This was the first detected example of artificial transmutation. The contributors to this record all bear witness to the paramount position which Rutherford held as the head of the teams with which he worked. He inspired and directed his co-workers and designed " experiments that asked Nature the most pertinent questions," brooding for long over the answers. A list of those who at one time or another worked with Rutherford would contain names which will stand in the forefront of any future history of twentieth-century physics—Chadwick, Bohr, Oliphant, Geiger, the list could be extended – but no one would be likely to deny to Rutherford his pre-eminent position as an experimenter nor in the words of Professor H. R. Robinson that his " genius was of a most uncommon kind," or in those of Dr. Russell that " he always saw further ahead in his work in physics than any of his contemporaries and saw more deeply."

These first five Rutherford lectures naturally deal to a considerable extent with the personality of the man. Dr. E. Marsden, in particular, in his interesting account of Rutherford's early years in New Zealand, paints an attractive picture of the home life of the lively and talented boy who having read a school book once, knew it. It was in a sense an accident that awarded Rutherford the 1851 Exhibition Scholarship which took him to Cambridge and changed the whole course of his life. The New Zealand university authorities at first recommended that the scholarship should be awarded to J. C. Maclaurin, a chemist, and it was only because Maclaurin was appointed Government Analyst that the scholarship passed to Rutherford, who at that time was at Canterbury University College and was experimenting with a detector of Hertzian waves. He was able to send and receive signals over the length of the laboratory. Professor Robinson suggests that " it is quite likely that he would have risen to fame mainly as a pioneer of wireless communication " had his interest not been turned to the subject of gaseous ionisation, under the influence of J. J. Thomson, shortly after his scholarship enabled him to proceed to Cambridge.

Ernest Rutherford never forgot that he was a New Zealander and had " a passionate belief in the British Commonwealth of Nations." No doubt his familiarity with Canada, where he spent eight years, contributed to his feeling that the Commonwealth was a unit. An incident recorded by Dr. Russell illustrates both Rutherford's pride in New Zealand and his bantering high-spirited nature. A certain bishop, meeting Rutherford at a luncheon, asked about the population of South Island and being told that it was about 250,000 seemed to think it could not be of much importance, pointing out that that was only about the population of Stoke-on-Trent. Rutherford was indignant at this apparent belittling of his lovely South Island and replied: " Maybe the population is only about that of Stoke-on-Trent, but let me tell you, Sir, that every single man in the South Island of New Zealand could eat up the whole population of Stoke-on-Trent, every day, before breakfast, and still be hungry." We recollect another incident, not recorded in this book, when Rutherford, during a railway journey, good-naturedly but pertinaciously " ragged " Kapitza about conditions in Russia.

In spite of his normal high spirits, Rutherford was subject to fits of depression and could be moved to anger, especially with those who maltreated apparatus. The depth of his scientific insight cannot be plumbed. His interest lay in a passionate search into Nature's secrets. Dr. Marsden records that he never exploited his scientific work for commercial ends and freely published information about any results he obtained. To speculate on what he would have thought about the edifice which has been erected on the foundations which he laid would be vain. It will not be suggested that Rutherford is to be given the credit, or the blame, for the atomic bomb but, as Sir John Cockcroft records, " the Liverpool branch of the Rutherford School . . . initiated the work on the atomic bomb which ended the war with Japan." What is certain is that Rutherford originated and did the fundamental work on which modern physics is based. It is given to few to inaugurate a new age; Rutherford stands among them. *Si monumentum quaeris circumspice.*

Periodicals and Serials: Their Treatment in Special Libraries. By DAVID GRENFELL. *Aslib, 4 Palace-gate, London, W.8.* (10*s.* 6*d.* to members; 12*s.* 6*d.* to non-members.)

As Miss E. M. R. Ditmas, former Director of Aslib, remarks in her foreword to this invaluable guide, articles in periodicals can be compared to statements made in conversation: open still to question, spot-lighting the growing points of a subject, without the delay necessary if the whole is to receive adequate treatment; stimulating, therefore, and fertilising. Some of the larger engineering firms in this country are " stimulated " by well over a thousand periodicals which they regularly receive, and even some of the smaller firms now subscribe to a range of periodicals which, in quantity, would have been considered outrageously large a generation ago.

Mr. Grenfell has made an admirable job of describing the orderly acquisition, handling and use of periodicals to serve the readers efficiently. Among the aspects treated are methods of keeping records of periodicals received; photograph reproduction (with some advice on copyright questions); and the relative merits of circulating periodicals, keeping them in the library, and a combination of both systems. The final chapter is devoted to the use of periodicals as works of reference: a use which, in the case of the better journals, is often more valuable than the week-by-week scanning. One small correction: the proceedings of the British Association are not published *in extenso* in the two journals named on page 121. The position is that the papers in Section G (Engineering) are practically all published *in extenso* in one journal only – namely, ENGINEERING – the British Association normally publishing only the presidential addresses.

BRITISH STANDARDS

The following publications have been issued by the British Standards Institution. Copies are available from the Sales Department of the Institution, 2 Park-street, London, W.1, at the price given after each title.

Impregnated Paper-Insulated Cables (for Electricity Supply) (Part 1: 6*s.* and Part 2: 5*s.*, both post free.)

A second revision of B.S. 480, dealing with paper-insulated cables, is now available. The standard was first issued in March 1933, and a first revision was published in May, 1942. The present revision is issued in two separate self-contained parts, namely, Part 1, covering lead or lead-alloy sheathed cables for working voltages up to and including 33kV, and Part 2, relating to aluminium sheathed cables for working voltages up to and including 22kV. Each part now contains " quality " clauses dealing with the composition of the various components of the cable. A basic reference temperature of 20 deg. C. for certain properties of annealed high-conductivity copper has been chosen. The practice adopted in the 1942 edition of specifying minimum and maximum diameters, over sheath and overall, has been abandoned in favour of nominal diameters. Tests are now divided into acceptance tests and sample tests. The former consist of conductor-resistance and voltage tests while bending and drainage tests are specified for use when required as sample tests.

Dimensions of Grinding Wheels (and Segments of Grinding Wheels.) (6*s.*, post free.)

Two standards for the dimensions of grinding wheels (B.S. 620) and for the dimensions of segments of grinding wheels (B.S. 671) were prepared and issued in 1935 and 1936, respectively. A revision of the two standards, published under one cover and designated B.S. 620 : 1954, has now been issued. In selecting the ranges of wheels to be specified every effort has been made to take account of the developments in grinding practice which have occurred since the earlier editions were published. The principle of simplification has been adhered to, but, in the endeavour to provide a truly practical specification, investigations have been carried out by the Abrasive Industries Association, working in close collaboration with the grinding-machine manufacturers. Tolerances on hole sizes, based on B.S. 1916, covering limits and fits for engineering, have been included and recommendations regarding drillings for inserted nut discs are also made, in an appendix. Part 1 of the standard relates to the dimensions of wheels for both non-precision and precision grinding. Part 2 gives the shapes and dimensions of segments, and lays particular emphasis on a range of preferred sizes.

Domestic Cooking Appliances for Use with Butane Gas. (6*s.*, post free.)

The first of a series of standards for domestic appliances using butane or propane gases has now been issued. It is B.S. 2491 and relates to domestic cooking appliances, ovens, hot plates, boiling burners and grillers consuming butane gas at 11 in. water-gauge pressure, and for use in the home or in caravans and houseboats. The standard specifies the construction, operation, and safety requirements of, and tests for, these appliances.

Drawing Office Equipment and Instruments. (Four specifications, all 2*s.*, post free.)

A further four standards, constituting part of a series of specifications covering drawing-office equipment and materials, have now been issued. They comprise: B.S. 2457 – protractors for drawing-office use; B.S. 2458 – French curves for drawing-office use; B.S. 2459 – set squares for drawing-office use; and B.S. 2460 – drawing instruments. Preferred sizes, based on current practice, are listed and recommendations are made for other dimensional requirements such as thickness, graduations and tolerances, with the object of establishing standard ranges of articles of sound quality. The standard sets recommended are: full set; medium set; and small set; to meet the needs of the expert draughtsman as well as those of the apprentice and the student. The properties of suitable metals for the manufacture of drawing instruments are set out, but no definite material is specified. Guidance, however, is provided on this subject. Manufacturing requirements are given in some detail, in order to ensure uniformity of quality in instruments supplied by various makers. The dimensions and material of needles, in particular, are clearly specified. A clause concerning suitable cases for instruments has been included in the specification.

TRADE PUBLICATIONS

Bulk Handling Equipment for Raw Materials. Various types of equipment and structures for handling coal, ore and other bulk materials are described in a 32-page illustrated booklet published by the Dravo Corporation, Neville Island, Pittsburgh 25, Pennsylvania, U.S.A. The booklet discusses mechanical, electrical and structural features of such equipment as ore and coal bridges, trolley unloaders, rope-operated towers, replacement trolleys, hydraulic buffers and rail clamps.

Chlorination of Water. Wallace & Tiernan, Ltd., Power-road, London, W.4, have reprinted as a booklet a paper entitled "The Chlorination of Water," by Mr. E. A. Whitlock. This paper was presented to the Institution of Sanitary Engineers on January 20 last, and deals in detail with the need for and the effects of the addition of chlorine to public water supplies.

Welding Stainless Steel. A booklet containing sixteen "notes" on welding stainless steel has been published by Rockweld, Ltd., Commerce-way, Croydon, Surrey. These cover various aspects of the subject, including recommended techniques for the different types. There is a chart at the end giving the types of electrode to be used with the various steels, and a table giving deposition rates.

Micro-focus X-ray unit. A leaflet issued by Hilger & Watts, Ltd., 98 St. Pancras-way, London, N.W.1, describes their micro-focus X-ray unit. This incorporates the Ehrenberg and Spear fine focus tube giving a spot approximately 0·04 mm. in diameter. The unit can be used equally well for X-ray crystallographic or micro-radiographic work.

Three-metre Spectrograph. Hilger & Watts, Ltd., 98 St. Pancras-way, London, N.W.1, have published a leaflet giving particulars of their three-metre grating spectrograph. The instrument is built in a very compact form and has a large range of accessories.

Insulating Tape. A booklet published by British Insulated Callender's Cables, Ltd., 21 Bloomsbury-street, London, W.C.1, lists their range of insulating and protective tapes. Eighteen tapes are described in detail and typical applications given.

Welding Stainless Steel and Zinc. We have received from Suffolk Iron Foundry (1920), Ltd., Sifbronze Works, Stowmarket, Suffolk, two leaflets, one describing in detail methods of welding stainless steel with either Sifsteel or Sifbronze and the other dealing with the welding of zinc.

Machine Tools. We have received from the Belgian Embassy, 103 Eaton-square, London, S.W.1, an illustrated booklet of 86 pages entitled "Belgian Machine Tools." It gives brief specifications in four languages of a wide range of standard and special-purpose machine tools built by the twelve members of "Sycomom" which is a Belgian Association of machine tool makers. Copies can be obtained from the embassy.

★ ★ ★

BOOKS RECEIVED

Constructional Steelwork Simply Explained. By OSCAR FABER. Third edition. *Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.4.* (12*s.* 6*d.*)

Floodlight: Guide to Evening Classes, 1954-55. *The Education Officer, The County Hall, Westminster Bridge, London, S.E.*1. (6*d.*)

British Standards Institution Yearbook, 1954. *British Standards Institution, 2 Park-street, London, W.*1. (12*s.* 6*d.*)

The Middle East. A Political and Economic Survey. Second edition. *The Royal Institute of International Affairs, Chatham House, St. James's-square, London, S.W.*1. (35*s.*)

Report on the Derailment which occurred on October 28, 1953, at Goswick, in the North Eastern Region, British Railways. Ministry of Transport and Civil Aviation, Railway Accidents. *H.M. Stationery Office, Kingsway, London, W.C.*2. (1*s.* 6*d.*)

Ecuador. Overseas Economic Survey. By N. MAYERS, C.M.G. Published for the Board of Trade, Commercial Relations and Exports Department, by *H.M. Stationery Office, Kingsway, London, W.C.*2. (2*s.*)

Aluminium in Building. Proceedings at a Symposium held in London, June 30, 1953. *The Aluminium Development Association, 33 Grosvenor-street, London,* W.1. (4*s.*).

FLOW OF A VISCOUS INCOMPRESSIBLE FLUID

EXPRESSIONS FOR A UNIFORM TRIANGULAR DUCT

By Henry Nuttall, PH.D., A.M.I.MECH.E.*

In the following discussion, numerical results are obtained for the volume of a viscous incompressible fluid flowing in unit time past the cross-section of a uniform triangular duct. The flow is assumed to be streamlined and end-effects at entry and exit of the duct are neglected. Although the results are derived on the assumption of incompressibility, it is reasonable to assume a gas to be incompressible for small pressure gradients. Thus, the solution will be of interest in the theory of viscous-flow air meters and has already found some application in that direction in the researches of Kastner and Williams.[1]

It is of interest to note that because of a mathematical analogy, the following solution is directly applicable to the determination of the torsional rigidity of a uniform solid shaft of triangular cross-section. This is indicated at the end of the article, where reference is also made to a more detailed discussion of this problem which is published elsewhere by the author.[2]

It is assumed that the cross-section of the duct has the form of an isosceles triangle in which the proportions are determined by the ratio $\frac{a}{b}$. The lengths a and b are as shown in Fig. 1. It is also assumed that the flow is laminar. For such a shape the volume of fluid passing any cross-section in unit time can be expressed as

$$V = \frac{C\,b^4\,P}{\mu\,L},$$

where P is the pressure drop over a length L of the duct, μ is the coefficient of viscosity of the fluid and C a number depending upon the cross-section ratio $\frac{a}{b}$. The values of C for ratios of $\frac{a}{b}$ ranging from 1·0 to 5·2 are tabulated below, Table I, and from these the flow through a duct of arbitrary isosceles triangular cross-section can be determined either directly or by interpolation.

TABLE I.—*Values of Coefficient C*

$\frac{a}{b}$	C	$\frac{a}{b}$	C	$\frac{a}{b}$	C
1·0	0·225	2·0	1·027	3·2	2·357
1·1	0·285	2·1	1·125	3·4	2·602
1·2	0·350	2·2	1·222	3·6	2·850
1·3	0·422	2·3	1·320	3·8	3·100
1·4	0·497	2·4	1·420	4·0	3·347
1·5	0·577	2·5	1·520	4·2	3·597
1·6	0·662	2·6	1·635	4·4	3·845
1·7	0·750	2·7	1·752	4·6	4·095
$\sqrt{3}$	0·7795	2·8	1·872	4·8	4·342
1·8	0·840	2·9	1·992	5·0	4·587
1·9	0·935	3·0	2·1132	5·2	4·837

The values of C corresponding to the cross-section ratios $\frac{a}{b} = \sqrt{3}$, and $\frac{a}{b} = 3$ give an exact value for the flow. All other values of C are derived by a Rayleigh-Ritz solution which, while giving a close approximation to the exact value of the flow must, of necessity, underestimate it slightly. The accuracy of the solution over the range considered is discussed below, where an outline of the method of solution is also presented.

* Department of Mechanical Engineering, The University, Birmingham.

When a viscous incompressible fluid is flowing steadily through a uniform duct under a constant pressure gradient as depicted in Fig. 2, the distribution of the velocity w over the cross-section is such that the rate of energy dissipation in friction exceeds twice the rate at which work is done by the external pressure, by an amount which is a unique minimum. Expressed analytically, this means that the energy integral

$$I = \mu L \iint \left\{ \left(\frac{\partial w}{\partial x}\right)^2 + \left(\frac{\partial w}{\partial y}\right)^2 - \frac{2\,P\,w}{\mu\,L} \right\} dx\,dy \quad (1)$$

taken over the region of the cross-section of the duct, is a minimum. This is readily seen by an argument on the lines of a discussion given by Lamb.[3] The determination of the velocity distribution w which makes I a minimum presents a standard problem in the calculus of variations, whence it is seen that w must satisfy the equation

$$\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} = -\frac{P}{\mu\,L}, \quad . \; . \quad (2)$$

over the cross-section, with $w = 0$ along the boundary of the section. Apart from a few simple shapes of cross-section an analytical solution of the last equation is out of the question and, for technical problems, the method of solution involves the use of relaxation methods or a Rayleigh-Ritz approximate solution.

A Rayleigh-Ritz approximate solution is obtained by substituting for the true velocity w a finite series of the form

$$\overline{w} = \sum_{r=1}^{r=n} B_r\,\theta_r, \quad . \; . \; . \quad (3)$$

where each θ_r is a suitable function of x and y and has zero value along the boundary of the section, and where B_r is a constant so determined as to make the energy integral I a minimum when $\overline{w}$ is substituted for w in equation (1). The minimising condition which determines the n constants is the set of n equations

$$\frac{\partial I}{\partial B_r} = 0. \; . \; . \; . \; . \; . \quad (4)$$

The accuracy of any such Rayleigh-Ritz solution depends upon the suitability of the functions θ_r chosen in the approximation, and it is a fundamental property of this method that

$$\iint \overline{w}\,dx\,dy < \iint w\,dx\,dy.$$

The physical significance of this is that the volume of fluid flowing as calculated by the Rayleigh-Ritz approximate solution is always less than the true flow.

EXACT SOLUTIONS

For a triangular cross-section, Fig. 1, exact solutions of the flow problem are possible when $\frac{a}{b} = \sqrt{3}$ and when $\frac{a}{b} = 3$, these cases corresponding to an equilateral and right-angled triangle, respectively. In other words, it is possible to solve equation (2) analytically for these two cases. It can be shown[2] that for these cases it is possible to express the velocity w as an infinite series of the following Rayleigh-Ritz type

$$w = \sum_r A_r\,\phi_r, \quad . \; . \quad (5)$$

where the functions ϕ_r are functions of x and y which are zero along the boundary of the cross-

section, and over the region of the cross-section satisfy the equation

$$\frac{\partial^2 \phi_r}{\partial x^2} + \frac{\partial^2 \phi_r}{\partial y^2} + \lambda_r^2 \phi_r = 0. \quad . \quad (6)$$

The eigenfunctions ϕ_r are an orthogonal set which have the property that any two distinct functions ϕ_r and ϕ_s, corresponding to distinct eigenvalues λ_r and λ_s, satisfy the condition

$$\iint \phi_r \, \phi_s \, dx \, dy = 0. \quad . \quad . \quad (7)$$

Substitution for w from equation (5) in equation (1) along with equations (7) and the equations corresponding to equation (4) leads to the determination of the coefficients

$$A_r = \frac{P}{\mu L \lambda_r^2} \iint \phi_r \, dx \, dy. \quad . \quad (8)$$

The volume flow is now obtainable by integration of the series for w, thus.—

$$V = \iint w \, dx \, dy = \sum_r A_r \iint \phi_r \, dx \, dy$$

$$= \frac{P}{\mu L} \sum_r \frac{1}{\lambda_r^2} \left[\iint \phi_r \, dx \, dy \right]^2. \quad (9)$$

In this way, the two exact solutions are indicated below.

(i) $\frac{a}{b} = \sqrt{3}$ (equilateral triangle)

$$\phi_r(x, y) =$$

$$\frac{2^{\frac{1}{2}}}{3b} \left(\frac{2}{3}\right)^{\frac{1}{2}} \left[2 \sin \frac{\pi n x}{3b} \cos \frac{\pi n y}{b\sqrt{3}} - \sin \frac{2 \pi n x}{3b} \right],$$

$$\lambda_r^2 = \frac{4 \pi^2 n^2}{9 b^2}, \quad \iint \phi_r \, dx \, dy = \frac{2^{\frac{1}{2}} 3^{\frac{1}{4}} b}{\pi n},$$

and

$$V = \frac{b^4 P}{\mu L} \frac{3^5}{2 \pi^4 \sqrt{3}} \sum_1^\infty \frac{1}{n^4} = \frac{1 \cdot 35 \, b^4 P}{\sqrt{3} \, \mu L}.$$

(ii) $\frac{a}{b} = 3$ (right-angled triangle)

$$\phi_r(x, y) =$$

$$\frac{\sqrt{2}}{3b} \left\{ \begin{array}{l} \cos \left[\frac{\pi}{6b}(m+n)x\right] \times \\ \qquad \cos \left[\frac{\pi}{6b}(m-n)y\right] - \\ \cos \left[\frac{\pi}{6b}(m-n)x\right] \times \\ \qquad \cos \left[\frac{\pi}{6b}(m+n)y\right] \end{array} \right\} \begin{array}{l} m \text{ odd}, \\ n \text{ even}, \end{array}$$

$$\lambda_r^2 = \frac{\pi^2}{18 b^2}(m^2 + n^2),$$

$$\iint \phi_r \, dx \, dy = 24 \sqrt{2} \frac{b}{\pi^2} \frac{n}{m(m^2 - n^2)},$$

and

$$V = \frac{20{,}736}{\pi^6} \frac{P b^4}{\mu L} \sum_{m \text{ odd}} \sum_{n \text{ even}} \frac{n^2}{m^2 (m^2 - n^2)(m^4 - n^4)},$$

which reduces to

$$\frac{20{,}736}{\pi^6} \frac{P b^4}{\mu L} \times$$

$$\left[\frac{\pi^6}{3{,}072} - \frac{\pi}{16} \frac{31}{32} \sum_1^\infty \frac{1}{n^5} - \frac{\pi}{8} \sum_{1,3,5}^\infty \frac{1}{n^5 (e^{n\pi} - 1)} \right].$$

This converges rapidly and is readily summed giving

$$V = 2 \cdot 1132 \, b^4 \frac{P}{\mu L}.$$

APPROXIMATE SOLUTIONS

When the ratio for $\frac{a}{b}$ of the cross section differs from the values $\sqrt{3}$ or 3, the solution proceeds in the usual Rayleigh-Ritz manner. One solution which will be a very close approximation in the neighbourhood of $\frac{a}{b} = \sqrt{3}$ is obtained by taking

$$\overline{w} = \Sigma B_r \theta_r,$$

where θ_r is taken as

(i) $\theta_r =$

$$\frac{2^{\frac{1}{2}}}{3b} \left(\frac{2}{3}\right)^{\frac{1}{2}} \left[2 \sin \frac{\pi n x}{3b} \cos \frac{\pi n y}{a} - \sin \frac{2 \pi n x}{3b} \right].$$

It will be seen that θ_r is zero along the boundary of the cross section and that, when $a = \sqrt{3}\, b$ $\theta_r = \phi_r$ as above, giving an exact solution. A second Rayleigh-Ritz solution which gives a very close approximation in the neighbourhood of $\frac{a}{b} = 3$ is obtained by taking

$$w = \Sigma B_r \theta_r$$

where θ_r is taken as

(ii) $\theta_r =$

$$\frac{\sqrt{2}}{3b} \left\{ \begin{array}{l} \cos \left[\frac{\pi}{6b}(m+n)x\right] \times \\ \qquad \cos \frac{\pi}{2a}(m-n)y \Big] - \\ \cos \left[\frac{\pi}{6b}(m-n)x\right] \times \\ \qquad \cos \frac{\pi}{2a}(m+n)y \Big] \end{array} \right\} \begin{array}{l} m \text{ odd}, \\ n \text{ even}. \end{array}$$

It will be seen that θ_r is zero along the boundary of the cross section and that, when $a = 3\, b$, $\theta_r = \phi_r$, as above, again giving an exact solution. Each of these Rayleigh-Ritz functions possesses certain orthogonal properties which lead to simplification in the evaluation of the energy integral I. These two solutions yield the following results:—

(i) $V = 0 \cdot 9 \frac{P}{\mu L} \frac{a^2 b^2}{a^2 + 3b^2}$

(ii) $V = \frac{13{,}824 \, a^2 b^2}{\pi^6 (a^2 + 9b^2)} \frac{P}{\mu L} \times$

$$\sum_{m \text{ odd}} \sum_{n \text{ even}} \frac{n^2}{m^2(m^2 - n^2)(m^4 - n^4) + \frac{32}{\pi^2} \frac{a^2 - 9b^2}{a^2 + 9b^2} m^4 n^2}$$

It is by evaluation of these expressions for different values of the ratio $\frac{a}{b}$ that the numbers C in the above table have been calculated, (i) giving an exact solution for $\frac{a}{b} = \sqrt{3}$, and (ii) an exact solution for $\frac{a}{b} = 3$. It remains to discuss the accuracy of these solutions over the range of values of $\frac{a}{b}$ for which they are tabulated.

ACCURACY OF EXPRESSIONS

Since the solution (i) is exact for $\frac{a}{b} = \sqrt{3}$, while solution (ii) is exact for $\frac{a}{b} = 3$, each solution serves to check the accuracy of the other for the range of vertex angles 60 deg. to 90 deg. It is possible by tabulation of the two solutions over the range $\sqrt{3} < \frac{a}{b} < 3$ to determine the ratio $\frac{a}{b}$ for which they yield the same value for the flow V. This ratio is found to be 2·5 corresponding to a vertex angle of about 80 deg. Recalling that a Rayleigh-Ritz solution must of necessity underestimate the value of the flow V, it follows that the ratio $\frac{a}{b} = 2 \cdot 5$ will be that for which the error is a maximum within the range $\sqrt{3} < \frac{a}{b} < 3$,

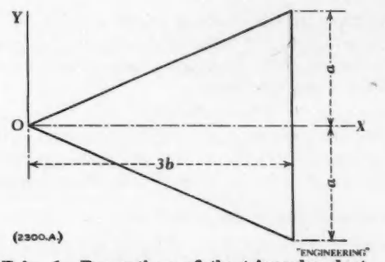


Fig. 1 Proportions of the triangular duct.

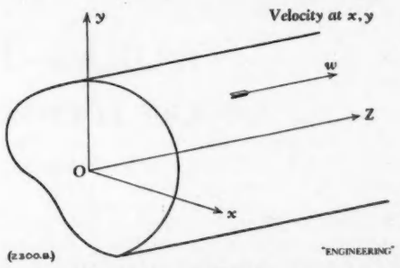


Fig. 2 The velocity distribution in a viscous incompressible fluid over the cross-section of a duct, when subject to a constant pressure gradient, is analogous to the distribution of the stress function in a shaft of similar cross-section to the duct, when subject to a uniform torque.

using solution (i) for $\frac{a}{b} < 2 \cdot 5$, and solution (ii) for values of $\frac{a}{b} > 2 \cdot 5$. A relaxation solution for $\frac{a}{b} = 2 \cdot 5$ shows the maximum error to be about 2 per cent.

For values of $\frac{a}{b} < \sqrt{3}$, a comparison made with the exact solution for the flow through a duct having a cross section in the form of a thin circular sector shows solution (i) to be in error by about 4 per cent. for a vertex angle of 40 deg., corresponding to a ratio $\frac{a}{b} = 1 \cdot 1$. For vertex angles smaller than 40 deg. the accuracy of solution (i) falls away rapidly and a better approximation is found by using the solution for a circular sector. To check the accuracy of the solution (ii) for ratios $\frac{a}{b} > 3$, a relaxation solution was obtained for $\frac{a}{b} = 5 \cdot 2$ corresponding to a vertex angle of 120 deg., giving a value of 4·812 for C. The value for C as determined by solution (ii) is 4·837 which, since it is of necessity in error by defect of the exact value, must be a closer approximation than the relaxation solution. Thus the accuracy of solution (ii) is well maintained for vertex angles in the range of 90 deg. to 120 deg., and the discussion may be summarised as follows.

The values of C as tabulated above give values of the flow V which are very accurate for vertex angles in the regions of 60 deg. and 90 deg. with a maximum error of about 2 per cent. at 80 deg., the accuracy being well maintained up to angles of 120 deg. For vertex angles below 40 deg. corresponding to $\frac{a}{b} = 1 \cdot 1$, a better approximation is obtained by regarding the triangle as a thin circular sector.

ANALOGY WITH TORSION

It will be appreciated that, because of the analogy existing between equation (2) of the present discussion and the equation for the stress

function in the problem of the torsion of a uniform shaft, the torsional rigidity of a uniform triangular shaft having a cross section as in Fig. 1 can be written as

$$T = 4 C b^4 G \theta,$$

where G is the modulus of shear, T is the torque producing an angle of twist θ radians per unit length and C is the number in the table above, corresponding to the section ratio $\frac{a}{b}$. Approximate expressions for the value of the maximum shearing stress can also be obtained. This problem has been discussed elsewhere[3] by the author.

REFERENCES

[1] L. J. Kastner and T. J. Williams, "Pulsating Flow Measurements by Viscous Meters with particular reference to the Air Supply of Internal Combustion Engines." Paper to be read before the Institution of Mechanical Engineers and to be published in the *Proceedings*.

[2] H. Nuttall, "The Torsion of Uniform Rods with particular reference to Rods of Triangular Cross Section." *Journal of Applied Mechanics*, vol. 19, No. 4, page 554. Dec., 1952.

[3] H. Lamb, *Hydrodynamics: General Theorems on Dissipation*, Art. 344.

WORKS TRANSPORT

MODERN EQUIPMENT AND PRACTICES

Concluded from page 277

We continue below our report of the two-day conference organised by the British Iron and Steel Research Association on "Works Transport" and held during early July.

MAINTENANCE WORK

Mr. C. E. Roebuck, Steel Peech and Tozer, next spoke on "The Maintanance of Works Transport." He emphasised the important part played by engineering in the great increase in steel output during the last 20 years. At his own works, whose annual output was approaching 1 million tons, transport represented about 15 per cent. of the total asset value of the plant. Planned maintenance had been in force at this works since 1947, backed by efficient workshops, extended and completed in 1951. Mr. Roebuck described the systems in force for railways, locomotives, rolling stock and power-operated handling vehicles.

The traffic department handled over 3,000 foreign wagons "in" and 3,000 "out" each week, in addition to the company's own wagons. About 44 miles of track were maintained by the platelayers divided into five squads of seven or eight men under a ganger. Emergency repairs at night were carried out by two men working on 12-hour shifts. The programme of repairs and renewals was prepared in advance and supplemented by routine examination for defects. Immediate attention was given to de-railments to make the track operative, and renewals were carried out with traffic still in operation by using prefabricated track sections. Rail and flange lubricators on rail curves reduced wear and lightened the platelayers' maintenance work.

There was a fleet of 20 steam locomotives and the repair shops were equipped to service up to five at a time. A wash-out plant and inspection pit were also available. Rebuilding at the rate of seven a year ensured that the lighter type were in service for 2 to 2½ years and the heavier for 2½ to 3 years between rebuilds. Rebuilding took 3 to 4 months and a standard operation layout was used for planning the work. Periodic running repairs were carried out every 4 to 6 weeks, the locomotive being withdrawn from service for 2½ to 3 shifts. Each locomotive was sent to the wash-out shop every 10 to 12 days for cleaning and tube sweeping, etc. The driver was responsible for daily lubrication and cleaning, but every three days a special squad cleaned the locomotive down. Boiler inspections were also carried out regularly.

They had had experience of Diesel-electric locomotives only since 1951. A daily inspection was carried out by the driver; a more thorough weekly inspection of battery charging, generator and voltage and other checks on filters, camshaft bolts, fuel-inspection systems, etc., were also necessary. Inspections were carried out in the repair shop monthly after 500 to 800 hours' operation and after 2,500 hours. After 20,000 hours all equipment was completely overhauled.

Mr. Roebuck said that he had looked into Diesel maintenance costs on learning of the 4*s.* 10*d.* per hour quoted by a previous speaker. He thought this a fair figure, as their own cost (including teething troubles) was 5*s.* 3*d.* per hour.

For steam locomotives, he thought the figure of 7*s.* 4*d.* was rather high. Their own costs worked out at 3*s.* 10*d.*, 4*s.* 1*d.* and 7*s.* 1*d.* in different years, the last mentioned year being one when he had had rather a large number of locomotives to repair. For 1954 the figure so far was 5*s.* 3*d.*

Diesel-driven handling vehicles, such as tractors, grab cranes, bulldozers and excavators, were given daily maintenance; oil sumps were drained every three months and refilled. Every 70 weeks, major repairs and complete engine overhauls were carried out in the repair shop.

Wood-and-steel works railway wagons (234 in number) and damaged foreign wagons were regularly inspected and minor repairs carried out in the sidings. More serious repairs were carried out in the wagon-repair shop. An average of 236 wagons had been repaired weekly to date in 1954. Steel wagons were subject to periodic inspection in groups of six. Ingot-casting cars, bogies, slag ladles, etc., were also given routine inspection and maintenance. Particular attention was paid to white-metal bearings which required adequate lubrication at all times.

ADVANTAGES OF ROAD TRANSPORT

Speaking on "Road versus Rail Transport," Mr. W. F. Cartwright (The Steel Company of Wales, Limited) said that whereas before the war few iron and steel works had any facilities inside their boundaries for road transport, no one would now build such a works without extensive provision for road traffic. Little exact data or statistics were available upon which to base a decision between road and rail, and he himself had few at his disposal. He hoped to give some statistics, however, in the full proceedings of the conference in due course.

Such data could not merely be concerned with road and rail transport costs per ton mile, nor were costs per locomotive-hour or per lorry-hour sufficient. It was necessary to discover how much a system cost as a whole. He questioned the value of comparisons between, for example, a 90-ton Diesel-electric locomotive of really first-class performance, capable of shifting an enormous train without effort and needing virtually no maintenance, and another locomotive, perhaps over-loaded, with various errors in design due to lack of experienced designers and other causes. Nor could one usefully compare a 5-ton Bedford with a 50-ton Buick. Each had duties for which it was most suitable.

Where comparisons were essential, it was necessary to ensure the fullest possible information. There was difficulty in obtaining accurate information of railway costs because of the poor instrumentation and absence of records. The type of rolling stock, for example, self-discharging wagons or non-self-discharging wagons would have a very large effect on the cost per ton-mile. In road transport, many different types of vehicles were often used and, for proper comparison, the costs of each type of vehicle must be kept separate.

A decision had to be made how railway and road transport systems were to carry charges for track and road respectively. There were certain jobs for which road seemed the only solution, such as the transport of parcels, personnel and odd items such as ladders and spares. There were certain items for which rail seemed the only solution, such as ingot traffic, iron traffic and hot-slag disposal. The difficulty of decision lay in the middle field exemplified by the transport of bricks, cold slag and the disposal of rubbish.

Mr. Cartwright then reviewed a particular decision between road and rail: that of transporting 3,000 tons per week of shale (soon to increase to 4,000 tons per week) from a large washery to the tip 1½ miles away. The bunker at the washery would hold only 100 tons. He admitted that the final decision in favour of road transport was at least partly based on a "hunch," although the deciding argument was the cost of the railway track and the fact that, since there was already a bunker at the washery, the bunkering facility of railway trucks was not needed. The fundamental point about road transport was that the vehicle must be kept on the move. Here there was an ideal case for a shuttle lorry service, cutting cost to a minimum. It was fairly simple to assess the total cost of the road transport required, but more difficult to assess that of rail transport, even when it was known how many locomotives of what particular types will be employed and for how long. The question was bound to arise: if the locomotive were used to do this particular job, would a locomotive shift be saved, or would the locomotive merely have more time to do the other jobs on its schedule?

However carefully the comparative costing was done, they still could not say how much money the company would expend in a year if it did the job by rail and how much money it would spend if it did the job by road.

Speaking for his own works, Mr. Cartwright said that they now handled by lorry everything that could be called an "article," such as an electric motor going to an electrical shop, or any breakdown material moving to the repair shops. They were changing over gradually to handling all bricks by lorry. He doubted, however, whether the decision had been arrived at by a proper costing system. Rather it was that the job was done more quickly, and it was felt that that must really be cheaper.

They were now carrying out a detailed costing for every kind of locomotive and for every locomotive, Diesel or steam. They were doing the same for every kind of lorry and for every lorry. In six months they hoped to produce a comparison between Diesel and steam locomotives and between road and rail.

In the discussion on Mr. Cartwright's paper it was suggested that, by diverting traffic from rail to road, the transport costs of the residual

rail traffic would be raised. Mr. Cartwright agreed that this would be so in a static works, but he had been speaking of a works which was increasing output by 50 per cent. The changes would afford opportunity for increasing utilisation of the existing rail system without capital expenditure and would enable them to scrap obsolete locomotives.

DIESEL OR STEAM

The last session of the conference was concerned with equipment, and opened with a paper by Mr. A. J. Harby (Steel Company of Wales, Limited), on "The Relative Merits of Diesel and Steam Traction." After pointing out that his paper was concerned only with the operation of fairly large locomotives on three shifts per day, Mr. Harby said that the advantages usually claimed for steam traction were low initial cost, reliability, simple maintenance requirements and ability to operate despite defects. Those claimed for Diesel traction were low fuel costs, high availability, no time for getting up steam and no stand-by fuel losses, cleanliness and pleasanter working conditions. All these must naturally be related to actual working costs.

Steam locomotives were used by the Steel Company of Wales, Limited, in the old works, but twelve Diesel locomotives (165, 480 and 660 h.p.) were used in the Abbey Works. Track conditions were good, with no curves less than 200 ft. in radius and with only one gradient (1 in 75 up) to the slag tips and high level stocking grounds. Even so, the 165-h.p. locomotives were found to be too small. The 660-h.p. were, on the other hand, unnecessarily powerful for normal traffic, though the average weight of trains tended to increase.

Mr. Harby said that the extra availability of Diesel locomotives had proved their worth, and ten more Diesel locomotives were on order for new plant extensions. The question whether to make a complete conversion to Diesel traction had now to be decided.

The costs of locomotive operation, apart from wages, were fuel, lubricant and consumable stores, maintenance, depreciation and capital charges. A saving of some 5*s.* 0*d.* per hour in fuel costs and small savings in lubricants and consumable stores could be made with Diesel locomotives. Maintenance was also cheaper compared with that for a steam locomotive not having special features to reduce maintenance (such as roller bearings on axle boxes and side rods, manganese liners on horn cheeks, etc.). By such means the maintenance costs of steam locomotives could be substantially reduced, but the advantage of lower capital costs of steam, normally little more than half that of Diesel, was correspondingly reduced.

On balance, a comparison of operating costs favoured the Diesel locomotive substantially. Moreover, if costs were based on actual working hours, the difference became even more marked.

Mr. Harby added that even greater financial advantages could be gained from complete conversion, with the consequent elimination of all steam maintenance and servicing facilities. He emphasised, however, that servicing and maintenance facilities must be first class, and also suggested the advisability of an incentive bonus for the locomotive crews to stimulate operation at the greatest availability. He thought it fair to point out that the use of high pressure, geared-drive steam locomotives had not been considered in the paper. They had tried one, but felt that since they were already committed to part Diesel working, they were better advised to consider the complete changeover.

The ten locomotives on order were of two types, though all were Diesel electric: one, a 45-ton, 300-h.p., 0-4-0 locomotive, and the larger, a 70-ton, 500-h.p., two-bogie locomotive. Great emphasis was laid on visibility in the new designs, and they were of very robust construction to withstand steelworks service.

Speakers in the discussion that followed commented on decisions taken under different operating conditions from those at the Abbey Works. At one works, where there were 36 steam locomotives dating from 1936 to 1953, standardisation was being carried out with consequent economies in maintenance. Because of good locomotive bunker capacity and handling equipment, the Diesel availability advantage was reduced to between half and one hour per shift.

The total savings on fuel and availability were important, but not exceptionally high, compared with other ways in which money could be spent in a steelworks plant. For Diesels to justify themselves, they must show other advantages as well. The reduction of smoke was a substantial gain, particularly in ingot traffic where much time was spent in and around buildings. At this works the introduction of two Diesel locomotives in about two years' time for this particular traffic was contemplated. The speaker favoured a locomotive with twin 200-h.p. engines, one at each end of the central cab, giving excellent visibility over small distances in both directions. There would be rather a long wheelbase with a 24-ton axle load. It was unlikely that they would ever buy another steam locomotive of conventional design.

A speaker from another works discussed his firm's decision to buy nine geared steam locomotives adapted for oil burning for use on new extensions. Capital costs were certainly lower than for Diesel, and it was expected that running costs would also be lower. Oil firing, combined with controlled combustion and, in particular, economy when idling, was hoped to give many of the advantages claimed for Diesel. Eight of the locomotives were 50-ton, 0-6-0 type. The other was a 90-ton special for two shift per day working on the coal sidings. This locomotive could be fuelled and watered sufficient for two shifts.

BULK-MATERIALS WAGONS

The last paper given to the conference was by Dr. H. R. Mills (B.I.S.R.A.) on "Wagons for Bulk Materials." Dr. Mills pointed out that, both in America and on the Continent of Europe, nearly all the bulk minerals used by steelworks are carried in four-axle bogie wagons of the hopper or side-discharge type, whereas in this country, with a few exceptions, two-axle wagons of either the hopper or flat type were used. The different policies were justified by the differences in conditions on the railways, the principal factor in favour of the two-axle wagon in this country being the restricted loading gauge.

Under comparable conditions of loading gauge and axle loading, there was little to choose between the best examples of each type as regards load/tare ratio. The use of large four-axle wagons gave fewer units to handle at terminals, but the larger handling equipment such as tipplers and weighbridges, which must be provided to handle four-axle wagons, could equally well handle two-axle wagons in pairs. A four-axle wagon might cost 50 per cent. more than two two-axle wagons.

When light materials such as coal or coke were carried under British conditions, a train of two-axle wagons was shorter than a train of four-axle wagons. When home ore was carried, two-axle wagons give somewhat longer trains with the present axle loading, but an increase of permissible axle loading to at least 20 tons, which would no doubt be brought about in due course by railway improvements, would remove this disadvantage. Any advance in the design and construction of lighter wagons using stronger or more corrosion-resistant materials would also favour two-axle wagons. Four-axle wagons would, however, give shorter trains for very heavy materials such as imported ore.

The same principles applied to wagons for internal use in works. Such wagons could usually be designed for a higher axle load and this favoured two-axle wagons except perhaps in new works in which extra wide or high wagons could be used.

An alternative to four-axle wagons for imported ore traffic might be the three-axle type such as was used in Sweden.

For any materials which were inclined to be sticky, such as home ores, emptying by side-discharge tippler or tippler hoist was the surest and quickest method, but involved uncoupling and handling wagons separately. The final choice between tippler and self-discharging wagons must depend to some extent on site conditions, and the process through which the ore or other materials was to be put after emptying the wagon. Side-discharge saddle wagons were easier to clear than centre-door hoppers, but the former had a lower capacity and were therefore longer.

Although loading and unloading as well as rapid handling at terminals were significant in the United Kingdom where runs were usually short, there was scope for some improvement in weight and speed of trains; in this connection brake wagons were an advantage. Braked trains, however, might cause more trouble at terminals if the layout and arrangements for filling and emptying involved uncoupling and handling of separate wagons.

The recommendations arrived at could be summarised as follow:

(1) For coal, and for bulk materials of light or moderate density generally, two-axle wagons should be used.

(2) Since British Railways had agreed that all new track and bridges would be designed for an axle loading of 22½ tons, and since considerably more home-produced iron ore than imported iron ore was transported, iron-ore wagons for general railway service should be of the two-axle type.

(3) Consideration should be given to four-axle or three-axle wagons for transporting imported iron ore from docks to works, provided that the traffic was sufficient to justify a shuttle service and to retain the wagons for this purpose only.

(4) All wagons should be designed to make the fullest possible use of the loading gauge, and works should ensure that their own loading gauge was not more restrictive than that of British Railways.

(5) Every effort should be made to introduce increased axle loading on all possible routes, and wagons should be designed with a view to future increase of the permitted axle loading to 22½ tons.

(6) All new track, tipplers, weighbridges and other equipment in works should be capable of handling wagons up to 45 tons gross weight, and should also be large enough to handle the new 12-ft. wheelbase coal wagons which are now being made.

In a final summing up, Sir Charles Goodeve emphasised that the services of B.I.S.R.A. for investigating transport problems were open to all. The subject of "Works Transport" had provided the material for an interesting two days and was worthy of further treatment in future conferences.

NIMONIC ALLOY DEVELOPMENTS

EXTRUSION NOW POSSIBLE

Nimonic 95 is a recent addition to this series of alloys* and, although an extensive survey of its properties – particularly those concerning creep over long periods – has not yet been completed, considerable information is now available. The heat treatment required to give the greatest creep resistance consistent with fine grain size over a wide range of hot-working conditions has been determined, as have the alloy's short-time high-temperature tensile properties (Table I). Certain creep characteristics of Nimonic 95, for temperatures up to 925 deg. C. and loading durations up to 10,000 hours, have been obtained (Table II) and fatigue properties as given by the rotating bend test have also been ascertained (Table III). These details, together with rotating-bend-test results for Nimonic 90 have been published by Henry Wiggin and Company, Limited, Wiggin-street, Birmingham, 16.

The greatest creep-resistance is normally obtained by solution-treating the alloy at as high a temperature as possible, but this can sometimes lead to the development of a coarse grain size, depending on the conditions of the prior hot-working. The recommended treatment which gives good creep properties and retains a fine grain size over a wide range of hot-working conditions is as follows. The alloy is held for 4 hours at 1,150 deg. C. and air cooled. It is then subjected for between 6 and 8 hours to a temperature of 1,080 deg. C. and again cooled in air. Following this it is held at 700 deg. C. for 16 hours, after which it receives a final air cooling. After this treatment, properties for Nimonic 95 of the order shown in Tables I, II and III have been obtained.

Initial solution-treatment for 1 to 2 hours at 1,200 deg. C. has been used instead of 4 hours at 1,150 deg. C., when a coarser grain size has not been regarded as unsatisfactory; the later steps of the treatment remain unchanged.

EXTRUSION

The use of Nimonic alloys in gas-turbine blading has permitted a continual rise in the gas temperatures employed and hence in output and efficiency; but as these temperatures approach those at which forging is carried out, the requirement that the alloys should be both stiff under operating conditions, and yet amenable to hot working, presents a serious problem. Cooling systems might enable further increases in operating temperature to be made and greater advantage to be taken of Nimonic-alloy properties, but the introduction of air passages into the blading adds to the difficulties of production.

* See ENGINEERING, vol. 177, page 620 (1954).

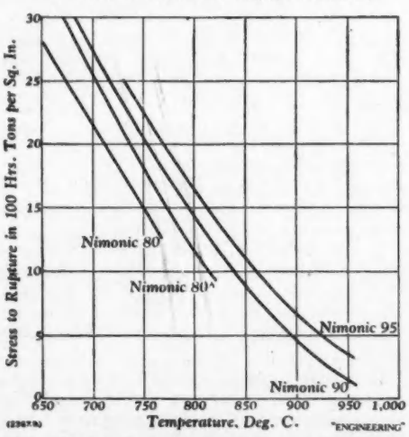


Fig. 1 The strength-temperature characteristics of four Nimonic alloys reveal the manner in which these materials have made possible increases in gas-turbine efficiency.

New advances have recently been made possible, however, by the application of extrusion to the Nimonic alloys. This has not only simplified the forming of blades with integral cooling passages but has also allowed an extension in the range of alloy compositions, thus providing materials of enhanced forging qualities.

The history of the Nimonic alloys has been closely linked with the development of the gas turbine and with the succeeding rises in gas temperatures specified by designers. To a remarkable extent the increasingly severe operating conditions have been met by these alloys, which have revealed properties regarded as unobtainable in any alloy only a few years ago.

From the introduction of the first high-temperature alloy in the Nimonic series, one or other has been employed for the moving blades of every British aircraft gas-turbine, and, in addition, the Nimonic alloys are now generally used for such components as flame tubes, stator blades, exhaust units and in fact for all vital components exposed to gases at high temperatures.

TURBINE-BLADE COOLING

Some indication of the improvements which have been achieved, is given by the curves in Fig. 1, from which it is apparent that the useful operating-temperature range has been steadily raised. Although progress has been considerable, the gas-turbine designer must also employ every artifice to utilise these properties to the utmost advantage; the subject of blade-cooling therefore has also received much attention, both in this country and abroad.

The problems involved are complex and although sweat, thermosiphon and other forms of liquid-cooling have been proposed, air cooling would appear to be the most convenient to apply. For this reason extensive production development work has been undertaken to produce blade sections with axial air passages. Methods which have been tried for the production of sections with a large number of small cooling passages include casting and sintering, but, in comparison with wrought materials of the same composition, castings have the disadvantage of being less uniform in properties and the technique of sintering has not yet been developed sufficiently to obtain adequate mechanical properties.

The development of an extrusion process for the Nimonic alloys has revealed many possibilities for further advancement. Service conditions necessitate the use of alloys which will be tough and stiff at high temperatures and yet must be suitable for hot-working. As new alloys have been added to the Nimonic series, there has been a corresponding reduction in the difference between the operating temperature, at which the alloy must be stiff, and the forging

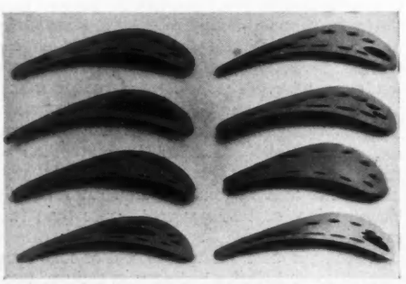


Fig. 2 A wide range of turbine-blade sections with integral cooling passages can be made by extruding Nimonic alloys, the forging qualities of which are improved by the process.

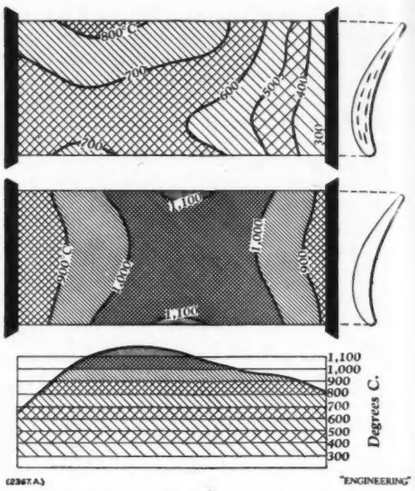


Fig. 3 The air-cooling of turbine stator blades permits improved heat distribution as indicated by these isothermal diagrams for units with and without cooling.

TABLE I.—SHORT-TIME HIGH-TEMPERATURE TENSILE PROPERTIES OF NIMONIC 95

Property	Temperature, deg. C.										
	20	100	200	300	400	500	600	700	800	900	1,000
0·1 per cent. proof stress, tons per sq. in.	51·6	49·3	48·5	46·5	46·3	46·0	44·3	43·0	31·1	17·1	4·12
Maximum stress, tons per sq. in.	81·9	76·0	77·9	75·1	72·0	72·1	64·7	51·5	40·1	21·9	6·2
Elongation per cent. on $\sqrt{\text{area}}$	25·1	21·9	20·6	20·6	21·4	23·6	13·7	4·5	4·5	10·9	59·3
Reduction of area, per cent.	24·1	25·5	21·9	24·6	25·3	28·1	19·5	7·1	6·4	12·5	48·0
Modulus, millions of lb. per sq. in.	30·5	29·8	30·6	29·3	29·3	27·3	26·4	25·1	22·0	17·9	14·1

TABLE II.—CREEP CHARACTERISTICS OF NIMONIC 95

Temp., deg. C.	Stress (tons per sq. in.) to Produce Creep Extension of																
	0·1 per cent. in				0·2 per cent. in					0·5 per cent. in				Rupture in			
	100 hrs.	300 hrs.	1,000 hrs.	5,000 hrs.	100 hrs.	300 hrs.	1,000 hrs.	5,000 hrs.	10,000 hrs.	100 hrs.	300 hrs.	1,000 hrs.	5,000 hrs.	100 hrs.	300 hrs.	1,000 hrs.	5,000 hrs.
750	20	16·5	13	9·2	22	18	14·5	10	8	23	19·5	15·5	10·5	23·5	19·5	16	11
815	11	8·5	6	—	12	10	7·5	—	—	13	10·5	8	—	13·5	11·5	8·5	—
870	7	5	2·7	—	8	6	4	—	—	8·5	7	5	—	9	7	5·5	—
925	—	—	—	—	—	—	—	—	—	—	—	—	—	5·0	3·8	2·2	—

TABLE III.—*Fatigue Properties: Rotating Bend Test*

Alloy	Temperature, deg. C.	Stress, tons per sq. in.	Endurance
Nimonic 90	815	$0 \pm 17{\cdot}4$	45×10^6 cycles in about 300 hrs.
	870	$0 \pm 12{\cdot}2$	
Nimonic 95	870	0 ± 20	10×10^6 cycles in about 65 hrs.
		$0 \pm 16{\cdot}8$	45×10^6 cycles in about 300 hrs.

temperature, at which it must be reasonably malleable. A stage may therefore be reached when alloys for still more onerous service cannot be forged economically by normal techniques.

EXTRUSION IMPROVES WORKABILITY

The extrusion process extends the range of composition of alloys which can be commercially worked, by breaking down the coarse structure of the cast ingot and thus improving forgeability so that ordinary hot- and cold-working operations can be used to give the desired final dimensions.

For some time the Zenith works of Henry Wiggin and Company, Limited, has been producing Nimonic aerofoil sections by hot extrusion and subsequent rolling. Work is now sufficiently advanced to enable a wide range of such forms (Fig. 2) to be successfully extruded, including those containing cooling passages of various configurations. It appears to be economically possible to produce cooled blade sections by this process, with passages only limited in number, size and shape by the operations involved in machining the original billet.

Fig. 3 reveals the effect of air-cooling on the operating temperatures of stator blades and on heat distribution. Cooled blade sections are currently being produced in Nimonic 80A and Nimonic 90. These blades offer all the qualities of Nimonic alloys in circumstances where resistance to oxidation and thermal shock is required, but, in addition, make these properties available for service with gas temperatures even higher than those employed at present, thus introducing further improvements in the overall output and efficiency of gas turbines.

SUBMARINE PIPELINE

PERMANENT INSTALLATION FOR UNLOADING TANKERS AT ACCRA

A submarine pipeline has recently been completed at Accra, Gold Coast, which is believed to be the longest of its type in the world. The pipeline is for unloading tankers, anchored in the roads 2½ miles offshore, into the shore tanks of the Socony Vacuum Oil Company (Gold Coast), Limited. The new line replaces a temporary "Pluto" installation which was built as an emergency measure during the last war.

The pipes used in the construction are 12 in. inside diameter and of a heavy section, supplied by Stewarts and Lloyds, 41 Oswald-street, Glasgow, C.1. They are served with bitumen and gunite coatings and are equipped with cathodic protection. Space allowed strings of pipes to be assembled on the shore ready for launching, as can be seen in Fig. 1. These strings were made up of 40-ft. lengths welded together, and covered with a machine-applied protective coating of two helical wraps of glass fibre paper set in hot coal-tar enamel. Over this was laid a light steel mesh gunited to a thickness of 3 in. to prevent damage and to give the pipe sufficient weight to rest firmly on the sea-bed. Some of the 1,400-ft. strings of pipe are visible in the background of Fig. 1.

In order to avoid damage during launching, it was decided to launch the pipe along the sea-bed rather than along the surface. However, the weight had been increased by the protective coatings from 50 lb. to 120 lb. per foot run and a special method had to be devised. In order to reduce the effective weight, pontoons were fixed at intervals along the pipe (as may be seen in Fig. 1) by straps of hoop iron. Thus the weight of the pipe in the water was reduced to about 3 lb. per foot run. To release the pontoons, a cutting device was fitted to the straps operated by a wire running the length of the pipe. After launching, this wire was drawn in, thereby releasing each of the pontoons in succession.

WELDED JOINTS

The friction of the pipe on land was reduced by using rocking cradles, shown in Fig. 2 in detail, spaced at 60-ft. intervals. Pneumatic-tyred wheels took the weight of the pipe without causing it any damage. These cradles also acted as guides for the pipe. As each section was launched, the next was lifted on to the cradles by crawler cranes and welded on, the joint being wrapped and coated after inspection. Throughout the work all welded joints were X-rayed using irradiated cobalt slugs. These reduced the amount of equipment required for inspection and also the work involved.

To tow the line out to sea, two tugs, the Vulcan and the Atlas (Government of Nigeria vessels),

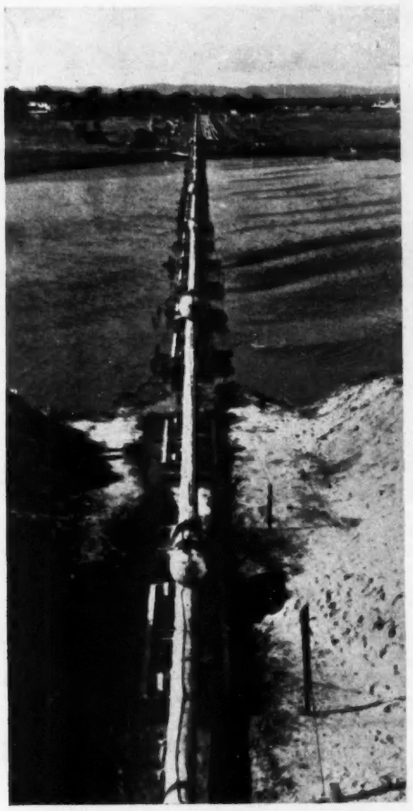


Fig. 1 The 2½-mile pipeline was made up in sections and drawn across the lagoon and sand-bank out to sea. It was carried on pneumatic-tyred rollers on land and partially supported by pontoons when on the sea-bed.

were employed. Movement was closely controlled by a 40-ton winch driven by a Diesel engine and located at the rear of the pipe spread. The back pull exerted by this winch allowed the rate of movement of the pipeline to be controlled whatever the pull the tugs were applying.

The 9-in. manilla hawser used between the tug and the pipe strings was about one mile long. This great length was necessary as the Vulcan could not be brought within ¾ mile of the shore; manilla was used, as a wire rope of the required length would have been too heavy to move when extended along the sea-bed. The hawser was specially made by British Ropes, Limited, Doncaster. Communication with the tugs was by short-wave radio, and telephones linked the winch-operator to a control tower and to points along the pipeline. A torsion dynamometer at the winch indicated the pull of the pipe. The launching operation was completed in 10 days and the whole task in three months, a time which is considered very satisfactory in view of the prevailing conditions.

LIFE OF 40 YEARS

Connection from the seaward end of the pipeline to the tanker is by a 300-ft. length of Neoprene hose. The tanker anchors at a buoy in the roads and recovers the hose from the sea-bed by its marker buoy. The hose is then connected to the discharge line of the tanker. It is estimated that the life of the installation will be at least 40 years in spite of the currents and heavy surf existing in the area. The main contractors for the project were Taylor Woodrow (West Africa), Limited, 10 Park-street, London, W.1.

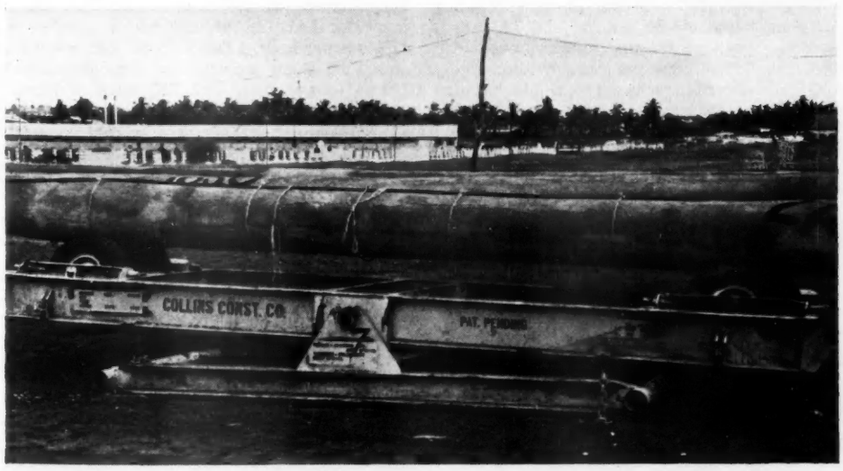


Fig. 2 The rocking launching-cradles were spaced at 60-ft. intervals. The weight of the pipe is carried by the centre rollers while the outer pairs act as guides. To avoid damage to the protective coatings the rollers have pneumatic tyres.

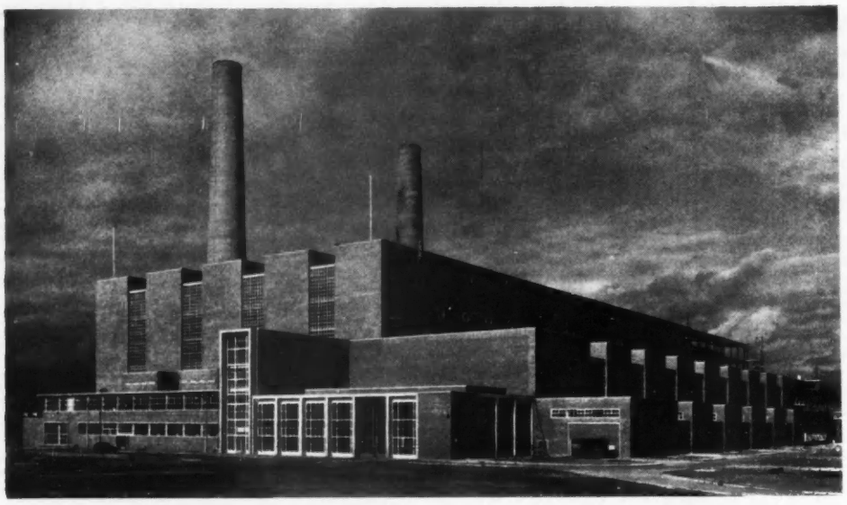


Fig. 1 Carmarthen Bay power station, the eventual installed capacity of which will be 345 MW, is built on the site of a disused copper works. Special foundations were required as standing water level is only 12 ft. below the surface.

345-MW POWER STATION AT CARMARTHEN BAY

DIFFICULT CIVIL ENGINEERING WORK INVOLVED

The Carmarthen Bay power station, which forms part of the generating capacity of the South Wales Division of the British Electricity Authority, was formally opened by Sir Henry Self on Friday, August 27. It is situated on a site of about 214 acres on the Burry estuary, near Llanelly, and will ultimately have a capacity of 345 MW, of which 105 MW is already in operation. It is hoped that the station will be completed in 1957.

Demolition and clearing work began in 1947, the first operation being the removal of metal slag and the derelict buildings which formed part of an old copper works. The ground level was raised some 8 ft. for the accommodation of sidings and 5,000 yards of roadway were built. Trial borings disclosed a thick seam of sandstone at a depth of 65 ft., above which were 40 ft. of grey silty sand interlaced with clay seams, 20 ft. of fine brown sand and finally the superficial slag deposits. As the standing water level was only some 12 ft. below the surface, an extensive de-watering system was installed to prevent the ingress of water into the deep foundations, which were laid about 40 ft. below ground level.

Some 5,500 reinforced-concrete piles with a cross section of 14 sq. in. and varying in length from 40 to 55 ft. were driven from excavation level to support the boiler and turbine houses, while a further 275 steel box piles were used to carry the ancillary buildings.

BUILDING LAYOUT

Both the main and ancillary buildings, as will be seen from Fig. 1, are constructed of steel framing with brick cladding. There will be three boiler houses, each being 225 ft. long and 220 ft. wide. These houses will be situated at right angles to the turbine room with the auxiliary switchgear annexes along each side. Each boiler house is to have a 300-ft. chimney constructed of brick and mounted on a reinforced-concrete pedestal. The turbine room is 740 ft. long and 96 ft. wide and the tank annexe and feed pump bay has been placed adjacent to it. The control room and generator, and the station and unit transformers are installed along its side while the main administrative block is at the west end. The 132-kV switch house, which is 440 ft. long by 110 ft., is on the east side of the main building.

The principal civil engineering contractors were Balfour, Beatty and Company, Limited, 66 Queen-street, London, E.C.4, while the steelwork was supplied by the South Durham Steel and Iron Company, Limited, Middlesbrough. The de-watering system was carried out by Millars Machinery Company, Limited, Bishop's Stortford, Hertfordshire.

COAL HANDLING PLANT

Coal is brought in by rail, there being siding accommodation for 600 loaded and 300 empty wagons. Each of the three boiler houses will eventually have separate wagon discharging and conveying equipment. This will be installed in duplicate for each house and will be capable of handling 150 tons per hour in all. The rail-borne coal for No. 1 boiler house, which may be regarded as typical of the general arrangements, is discharged by a tippler of the Rota Side type with a capacity of 240 tons per hour manufactured by Strachan and Henshaw, Limited, Bristol, into a receiving hopper. It is removed thence by duplicate electric vibrating feeders on to 24-in. belt conveyors, 307 ft. long, which run at a speed of 200 ft. per minute in a tunnel under the railway sidings to the boiler house. These conveyors are provided with a magnetic head pulley and a suspended magnet for the removal of tramp iron and discharge into gravity bucket conveyors, which are installed in the base of the chimney. These conveyors raise the coal through a height of about 48 ft. and deliver it into crushing plant. It then passes over Niagara screens where the non-metallic rubbish is removed.

After passing through the screens the coal descends to rotary fillers and thence to the main gravity bucket conveyors which elevate it through about 92 ft. and carry it a distance of about 174 ft. over the boiler-house bunkers. During their horizontal run each bucket conveyor passes over dumpers, of which there are four per bunker pocket, so that full advantage can be taken of the capacity of each. The coal is discharged from the bunker outlets through water collecting gates and chutes to the pulverising mills mentioned below. These chutes are interrupted so that fuel can also be passed into removable test weighers at the firing floor level.

Each of the conveyors has a capacity of 75 tons per hour and are electrically driven by motors manufactured by the British Thomson-Houston Company, Limited, Rugby. The motors driving the belt conveyors have an output of 7·5 h.p., the corresponding outputs for those on the gravity bucket conveyors in the chimney base and on the main gravity bucket conveyors being 16 h.p. and 35 h.p. respectively.

An important feature of this handling plant, the main contractors for which were Babcock and Wilcox, Limited, Farringdon-street, London, E.C.4, is that by utilising the space in the chimney base none of it is visible externally. Gantries, which might otherwise have spoilt the architectural features of the building, have therefore been avoided. Due tribute has in this way been paid to æsthetic considerations.

Alternatively, the coal can be discharged by a second tippler on to a conveyor which was manufactured by Rhymney Engineering Company, Limited, Cardiff, and has a capacity of 125 tons per hour. This delivers it to a storage area, which is capable of accommodating 140,000 tons of coal. This coal can be re-claimed

Fig. 2 Some of the mills from which pulverised semi-bituminous coal is supplied to the boilers.

Fig. 3 One of the boiler house aisles showing the separate control panels with the master control board in the background.

by bulldozers and carry-alls, which transfer it to a travelling telpher with a capacity of 100 tons per hour whence it is discharged into rail wagons for carriage to the boiler house tipplers.

STEAM RAISING ARRANGEMENTS

Each of the three boiler houses is designed to accommodate six boilers each with an output of 240,000 lb. of steam per hour at a pressure of 940 lb. per square inch and a temperature of 925 deg. F., the temperature of the water at the economiser inlet being 365 deg. F. One boiler house containing five boilers has been so far completed. The other two will also contain five units with space for a sixth. The fifteen units will, however, provide sufficient steam for the operation of six sets running at full output.

The steam raising plant, which has been supplied in its entirety by Babcock and Wilcox, Limited, consists of a high-head boiler, the steam drum of which is about 4 ft. 6 in. in internal diameter, the tube plate being 3⅛ in. and the wrapper plate 2 $\frac{9}{16}$ in. thick. Each drum is fitted with a cyclone steam separator. The steam generating tubes are straight and are expanded into forged headers. The furnaces, which have a volume of 21,900 cub. ft. and are lined with Bailey blocks, are water-cooled and are designed for burning pulverised semi-bituminous coal with a minimum volatile content of 13 per cent. and a maximum ash content of 15 per cent.

This coal is pulverised in pressure-type mills, which are illustrated in Fig. 2. There are three mills to each boiler the supply to which is made through nine vertical intertube burners. These burners are located in an arch near the top of the furnace and fire downwards. Each boiler is also fitted with two retractable pressure-atomising oil burners for lighting up purposes. These are automatically inserted through ports when the oil pressure is applied, are ignited by a spark from a high tension transformer and are retracted when the oil pressure is turned off. A boiler house aisle is illustrated in Fig. 3.

The superheaters are of the Babcock multi-loop type, there being two surface attemperators for the control of the final steam temperature between the primary and secondary stages. The primary stage has a heating surface of 8,150 sq. ft. and consists of 76 tubes with an external diameter of 2 in. These are arranged in two banks, each six loops high, the first being of carbon steel and the second of ½ per cent. molybdenum steel. Alloy steel (Esshete CML) is used for the secondary superheater, which has a heating surface of 2,900 sq. ft. and is composed of 58 2¼-in. diameter tubes arranged in five loops. The headers, into which the superheater tubes are expanded, are 12 in. in diameter.

The economisers, which are also of the multi-loop type, have a heating surface of 9,600 sq. ft. They are arranged in two banks in parallel on the water side and are designed to increase the temperature of the feed water from 365 deg. to 502 deg. F. There are two rotary air heaters for each boiler, which raise the temperature of the combustion air to 533 deg. F. at the maximum continuous rating. These heaters were manufactured by James Howden and Company (Land), Limited, Glasgow, and have a heating surface of 34,200 sq. ft. Draught is provided by two forced-draught and two induced-draught fans, manufactured by Davidson and Company, Limited, Belfast. The output of the former is 39,700 cub. ft. and of the latter 62,000 cub. ft. of air per minute. There are also two primary air fans, each with a maximum output of 26,000 cub. ft. of air per minute, and three sealing air fans. Grit arresters, manufactured by Prat-Daniel (Stanmore), Limited, Stanmore, Middlesex, with a capacity of 60,800 cub. ft. of air per minute, and electrostatic precipitators are also provided for each boiler.

ELECTROSTATIC PRECIPITATORS

The electrostatic precipitators were supplied by the Sturtevant Engineering Company, Limited, Cannon-street, London, E.C.4, and are of that firm's standard type. They are housed in a concrete casing, of which the inlet flue forms an integral part, and consist of nests of earthed tubular receiving electrodes. A discharge electrode, which is connected to a uni-directional high-voltage supply is suspended inside each tube. The solid matter in the gases is driven by the ionised field between these two electrode systems against the walls of the tubes to which it adheres, and from which it is released by automatic rapping gear, the dust thus precipitated being collected in hoppers. The high tension equipment is of the mechanical rectifier type, there being a separate unit for each precipitator. These units are electrically connected in groups of three, so that any of them can operate any precipitator in that group.

ASH HANDLING

Each of the five boilers in the first house is fitted with a dry ash hopper, the contents of which is discharged periodically into sluice ways and thence into a sump. The ash, together with the dust from the arrestors, precipitators and flues, is then pumped to an 85-acre site on the east side of the station. The ash, sealing and overflow pumps are provided in duplicate and, as the length of the discharge line is 5,000 ft., two booster pumps, with an output of 1,600 gallons per minute, have been installed.

The second and third boiler houses will be equipped with similar plant but will, however, incorporate water-filled hoppers. The three hoppers will be interconnected so that they can deal with adjacent boiler houses in an emergency. The high pressure sluicing water is supplied by pumps which have been installed in the circulating water pump house. The main contractors for this portion of the plant were B.V.C. Industrial Constructions, Limited, Leatherhead, Surrey.

SOOT BLOWERS

Each steam raising unit is provided with 22 soot blowers. Of these, 18 are installed in the furnace and superheater and are of the Babcock pilot-valve retractable single-nozzle type. The remainder, which are installed in the air heater, are Babcock-Howden fixed element blowers. An automatic sequence control of the Babcock-Lockheed hydraulically operated pattern is used for operation. This is arranged to give fully automatic control of the range, to suppress a particular blower from the cycle or to operate a selected blower. Manual operation is also possible; if, during operation, a blower head fails to complete its duty within a given time, blowing ceases and an alarm is sounded.

Each boiler is equipped with its own control panel as can be seen in Fig. 3, while there is also a master control board in a separate glass-partitioned room, which is visible in the background of the same illustration. Instrumentation is very complete and includes boiler, superheater and feed water pressure gauges, water level indicators, water flow meters, temperature recorders and indicators, carbon dioxide indicator and draught gauges. There are also switches and ammeters for the fans, classifiers and pulverisers, an illuminated indicating diagram with pressure gauges and switches for the soot blowers, and motorised equipment for the Lockheed dampers.

The master control panel also carries a pressure gauge, valve controllers and indicators, steam flow and temperature indicators, and a carbon dioxide recorder as well as the automatic control equipment and apparatus for adjusting the superheater steam temperature.

Steam from the boilers is delivered to a receiver of which there is one for each turbine. It will be possible to interconnect the six receivers, which will eventually be installed, either separately or in pairs so as to make the best use of the boiler capacity.

TURBINES AND FEED HEATING PLANT

The present generating plant consists of two three-cylinder turbines, which were manufactured by Metropolitan-Vickers Electrical Company, Limited, Manchester and are direct-coupled to an alternator. The output of each set is

Fig. 4 Foundations of circulating water pump house which was constructed on reclaimed land along the foreshore of Burry estuary.

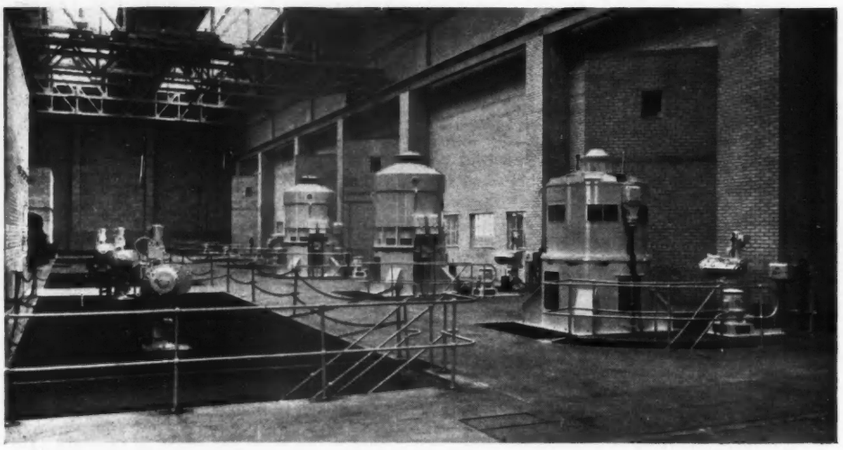


Fig. 5 Some of the circulating water pumps.

52·5 MW at 11·8 kV, when running at 3,000 r.p.m. These alternators are air-cooled, but the other four sets will be cooled by hydrogen at a pressure of 0·5 lb. per square inch and will each have an output of 60 MW.

The high-pressure cylinder of each of the existing turbines consists of eleven impulse stages, while there are 14 stages in the intermediate pressure cylinder and five in each half of the double flow low-pressure cylinder. The blading throughout is of stainless steel. The arrangement of the 60-MW turbines will be similar, except that there will be only 13 stages in the intermediate pressure cylinder. The designed heat and steam consumptions at full load are 9,390 B.Th.U. per kilowatt-hour and 8·433 lb. per kilowatt-hour in the case of the 52·5-MW sets and 9,250 B.Th.U. per kilowatt-hour and 8·429 lb. per kilowatt-hour in the case of the 60-MW sets.

After passing through the existing turbines the steam is exhausted into twin condensers, each set being capable of dealing with 330,000 lb. of steam per hour when cooled with 44,000 gallons of water per minute. The vacuum is 29 in. with the barometer at 30 in. and a cooling water temperature of 58 deg. F. The capacity of the condensers for the remaining four sets will be 377,000 lb. per hour, their cooling surface being 60,000 sq. ft. Air is extracted by two three-stage steam-operated ejectors.

The condensate is withdrawn by vertical pumps, which deliver it direct to the two low pressure heaters in the five-stage feed-heating system and thence through a high level full duty de-aerator, to the feed pumps and to two high pressure heaters. The final feed temperature of the water supplied to the existing boilers is 365 deg. F. This feed heating plant was also supplied by the Metropolitan-Vickers Electrical Company, Limited. At present three electrically-driven and one steam-driven feed pump are installed, the former being manufactured by the Harland Engineering Company, Limited, Alloa, and the latter by G. & J. Weir and Company, Limited, Cathcart, Glasgow, C.4. The separate output of all these pumps is 550,000 lb. per hour. The pipe work on both the suction and discharge side is arranged so that one electrically driven pump acts as a stand-by to the others, while the steam-driven pump can operate as a standby to any of the electrically-driven pumps in case of emergency.

Make-up water is obtained from the town's unfiltered supply and is treated in softening and evaporating plant. The present softening plant has a capacity of 40,000 lb. per hour, while that of each of the live-steam triple-effect evaporators, which were manufactured by Aiton and Company, Limited, Derby, is 20,000 lb. per hour. The feed water is treated by injecting chemicals into the suction line and boiler drums. The clean drainings are collected in a tank, an arrangement which facilitates emptying the boiler without losing the feed water.

CIRCULATING WATER SYSTEM

The house, containing the pumps by which water is drawn from the Burry estuary for cooling purposes, is situated on the foreshore, a portion of which was reclaimed by building an embankment 30 ft. high by 700 ft. long on the seaward side. As there is a tidal rise and fall of 30 ft. in the estuary the foundations were carried down to a considerable depth, in order to drown the suction inlets of the pumps under all conditions.

Excavation was therefore carried out within a sheet pile cofferdam, a reinforced-concrete diaphragm, 2 ft. thick, in which a circular opening was left, being then cast 5 ft. below ground level. After this diaphragm had been placed excavation proceeded underneath it and a second diaphragm was inserted. This process was repeated successively until six diaphragms had been placed in position, the last of which formed the base of the pump house. This work is shown in progress in Fig. 4, on page 305.

Common bricks and Winget blocks were used for vertically shuttering the internal faces of the cylindrical cells, while the reinforced-concrete walls, which were built up round the various openings to form a number of deep cylindrical chambers were constructed using a travelling shutter. These chambers are now used for housing the pumps, screens, penstocks and other equipment. The interstices on the outside of the cylindrical walls, which are not required for plant, have been back-filled with sand, but the cofferdam piling to which the diaphragm reinforcement was welded has been left in place. The part of the pump house below ground level was built to form three sections, which are solely connected by waterways in which sluice gates have been installed. The intake and outlet culverts, which are naturally subject to the same tidal conditions as the pump house, were also partly constructed on the foreshore, the bulk of the work being carried out between the high water and beyond the low water levels. Actual installation was effected in sections within sheet steel cofferdams, from which the sand was pumped on to the foreshore; the contractors for this portion of the station also being Balfour, Beatty and Company, Limited.

The inlet culvert to the pump house is about 300 ft. long, its invert level being 25 ft. below Ordnance Datum, while the discharge culvert is 560 ft. long and its invert 20 ft. below Ordnance Datum. Both culverts were constructed of reinforced concrete using a travelling shutter and have an internal cross-section of 19 ft. by 15 ft.

The intake and outlet flumes between the pump house and the station are spun concrete pipes. They are embedded in reinforced concrete to form a continuous cellular block three flumes wide and three deep. Six of these flumes, which run the length of the station, will be used as inlets and three as discharges. This civil engineering work has been constructed to fulfil the requirements of the station when finally completed.

CIRCULATING PUMPS

The circulating water pump house, of which a view is given in Fig. 5, contains three vertical-spindle two-stage axial-flow pumps. Each of these pumps, which were manufactured by Vickers-Armstrongs, Limited, Broadway, London, S.W.1, has an output of 52,600 gallons per minute against a total head of 25 ft. when running at 356 r.p.m. These pumps are driven by 935/193-h.p. motors of Laurence, Scott and Electromotors manufacture with a speed range of 472 to 262 r.p.m. Four other pumps which will be driven by 560-h.p. British Thomson-Houston motors at a constant speed of 356 r.p.m., will be installed, this difference being necessary owing to the large tidal range. The pumps draw the water in through 60-in. screens of the central flow band type, which were constructed by F. W. Brackett and Company, Limited, Colchester, and pass it through a surge shaft and the inlet flumes to the condenser. Each condenser is supplied with water by one pump, the other being a stand-by. The discharge is taken through one of the three outlet flumes to the outfall some 1,080 ft. upstream from the intake.

ALTERNATORS

Each turbine is directly coupled to an alternator with an output of 61·765 MVA at a power factor of 0·8, which generates three-phase current at 11·8 kV and a frequency of 50. These machines are of standard Metropolitan-Vickers design with fabricated stators, the windings being of the involute type. The rotors are single forgings. Excitation is provided from direct-coupled main exciters and overhung pilot exciters. A view of the present sets is given in Fig. 6. Air cooling on the existing alternators is provided on the closed circuit system circulation being effected by separate fans, which maintain a pressure slightly above atmospheric.

TRANSFORMERS AND SWITCHGEAR

Each alternator is solidly connected to a main 63 MVA, 11·8/141·6-kV transformer, which was manufactured by Asea Electric Limited, Fulbourne-road, Walthamstow, London, E.17.

These main transformers are of the water-cooled type with on-load tap changers. The other four transformers will have an output of 72 MVA with the same voltage ratio. These transformers are connected through single-core oil-filled cables of Pirelli-General manufacture to the main 132-kV switchgear, which was constructed by Ferguson Pailin Limited, Higher Openshaw, Manchester, 11. This switchgear, which is of the air-blast pattern, is installed in a large " hall " type building, which is separated by a central wall and various plant rooms into east and west switch houses. This unusual arrangement protects the equipment from salt-spray and has also resulted in a saving of space.

The circuit-breakers themselves are mounted in two rows on each side of the switch house, which is 320 ft. long by 90 ft. wide by 50 ft. high, the generator, station transformer and bus-coupler circuits being on the south and the feeder circuits on the north. The feeder and bus-bar protective gear, compressed air and carbon dioxide fire-fighting equipment, low voltage distribution boards and the main bus-bar protection switch are housed in a central block. The cables and air lines are in a basement of cellular construction with 92 compartments, which provides a rigid floor. The bus-bars are suspended from the roof trusses by solid-core insulators and are 38 ft. above floor level. The main bus-bar runs down the centre of the building and has a section switch with through-wall bushings. The reserve bus-bar is in the form of a double U, the two parts of which are coupled by isolators. Access to the bus-bars is obtained by trolleys, which are suspended from rails running between the phases. When not in use these trolleys are parked on platforms at each end of the building.

The generators and station transformers are connected to the bus-bars by cables which terminate in sealing ends mounted in separate compartments on the south side of the building. The incoming lines terminate on towers outside the building and are brought in through synthetic resin-bonded condenser bushings.

The air-blast circuit breakers, one of which is illustrated in Fig. 7, are, with the exception of the insulators supporting the fixed isolator contacts, of the same design as the firm's standard outdoor equipment. Each circuit breaker comprises three single-phase units which incorporate two interrupter heads, these heads being arranged in series on one side of the equipment. Separate control units are provided on each phase, but all three phases are coupled pneumatically to guard against failure of a particular trip coil. Each circuit breaker is enclosed in a wire-mesh screen, in the corner of which the local operating and marshalling kiosk is mounted so that access to it can be obtained from the passage way.

ISOLATOR DESIGN

The isolators are of the single-break type, the moving contact being arranged to operate in a vertical plane. The three phases are mechanically coupled and are operated manually from ground level. The bus-bar isolators are mounted vertically on the main steelwork inside the building, while the feeder isolators are arranged horizontally on floor structures. Access to the bus-bar isolators is obtainable from a walkway in the main steelwork, and hinged platforms can be lowered between the phases for maintenance purposes. These platforms are interlocked, so that they can only be lowered when the particular bus-bar is earthed. When the bus-bars are alive the platforms form part of the screenwork on either side of the walkway.

Air for operating the circuit-breakers is obtained from duplicate banks of compressors. At present there are two compressors in each bank, although a third will be added later. These compressors supply air at a pressure of 650 lb. per square inch to main storage receivers, whence it is fed through valves (which reduce the pressure to 300 lb. per square inch) to a ring main and thence to the individual circuit-breaker receivers.

Along the south wall there is provision for six generator, two station transformer, and two bus-coupler circuits, while along the south wall is similar provision for eight feeder and two reactor circuits. The feeders are all overhead lines, two of which run to Tir John near Swansea with supply points at Llanelly and Trostre. A third will be connected to Ebbw Vale and a fourth to the Upper Boat power-station, each with supply points at Hirwaun, Ystradgynlais and Ammanford. A fifth will be connected to Carmarthen and a sixth to Haverfordwest, the remaining two being spare. These lines were erected by British Insulated Callender's Construction Company, Limited.

The circuit-breakers are controlled from panels of conventional design, which are installed in a room in the power station. These panels incorporate a mimic diagram, which is normally dark, and discrepancy-type control switches and semaphores. The relay panels for the generator and station transformers are installed in an adjacent room, while those for the feeder and bus-bar zone protection are in the switch-house itself.

AUXILIARY SUPPLY ARRANGEMENTS

Power supply for the station auxiliaries is obtained from two 10-MVA, 132/3·457-kV station transformers and six 6-MVA, 11·8/3·457-kV unit transformers. These transformers, all of which were manufactured by Asea Electric, Limited, are connected to a 3·3-kV network through air-break truck-type switchgear, which was manufactured by the British Thomson-Houston Company, Limited, Rugby. This switchgear is installed on two main switchboards, which control 14 and four circuits respectively, and on two unit-switchboards which control nine and eight circuits. In addition, there are five boiler house boards each controlling five circuits, and six pump-house switchboards each controlling six circuits. There are also two double-circuit isolator cubicles for controlling the ash-pump motors.

A low-voltage supply is given through air-cooled transformers, manufactured by Hackbridge and Hewittic Electric Company, Limited, Hersham, Walton-on-Thames, Surrey, the capacities of which are 250 kVA and 500 kVA and the ratio of transformation 3·3 kV/433 volts. The 433-volt circuits connected to these transformers are controlled by British Thomson-Houston switchgear of the air-break type with a rupturing capacity of 25 MVA, including both truck and double-tier draw-out designs. In addition, there are five switchboards carrying air-break contactors for the boiler control equipment and one for the coal-handling plant.

A 150-kVA emergency Diesel set, manufactured by the National Gas and Oil Engine Company, Limited, Ashton-under-Lyne, is installed to maintain the essential services in case of a complete shut down of the other plant. Direct current for operating the 132-kV and other switchgear, and for supplying some of the emergency lighting, is obtainable from a battery supply installed by the Alton Battery Company, Limited, Alton, Hampshire.

Work on the site was begun by the Carmarthen Bay Power Station Company and was continued after vesting day under the supervision of Mr. H. V. Pugh, who was then Controller of the South Wales Division, and of Mr. T. H. Wood, Chief Generation Engineer (Construction). It was continued under Mr. H. J. Bennett and Mr. C. W. Priest, who are, at present, respectively, Controller and Chief Generation Engineer (Construction) for the Division.

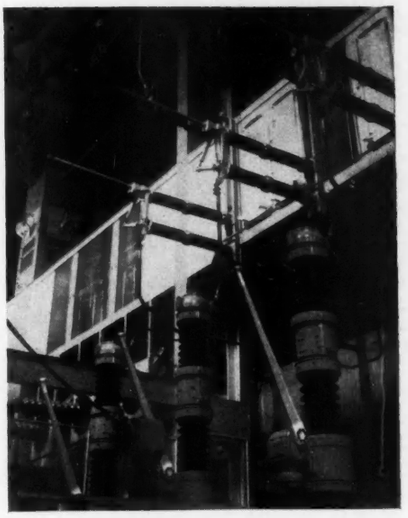


Fig. 7 132-kV air-blast circuit-breaker showing the interrupter heads.

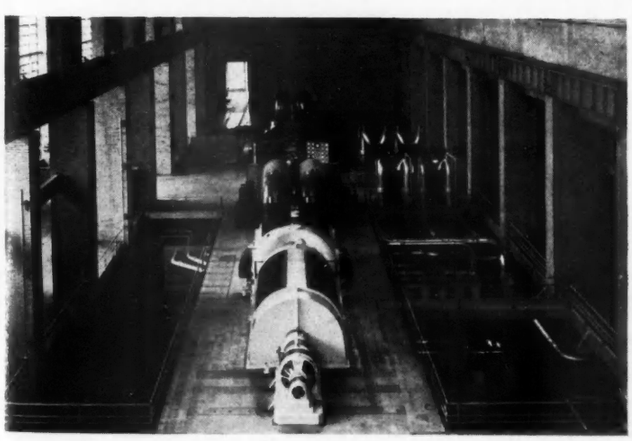


Fig. 6 The turbine room at Carmarthen Bay power station showing the existing 52·5 MW turbo-alternators.

★ ★ ★

ELECTRICITY SUPPLY IN JULY

9·1 per cent. Increase

During July, 1954, 4,489 million kWh were sold by the British Electricity Authority to the Area Boards. This was an increase of 10·8 per cent. over the figure of July, 1953. When corrected for the weather, which was much colder than a year earlier, and for the number of working days, which were less, the increase was, however, 9·1 per cent. The amount of electricity sent out by the Area Boards was 4,383 million kWh, while 106 million kWh were supplied direct by the central Authority. The amount distributed in the " mainly industrial " areas was 2,827 million kWh, an increase of 9·4 per cent. over the corresponding period in the previous year; and 1,556 million kWh in the " mainly non-industrial " areas, an increase of 12·5 per cent.

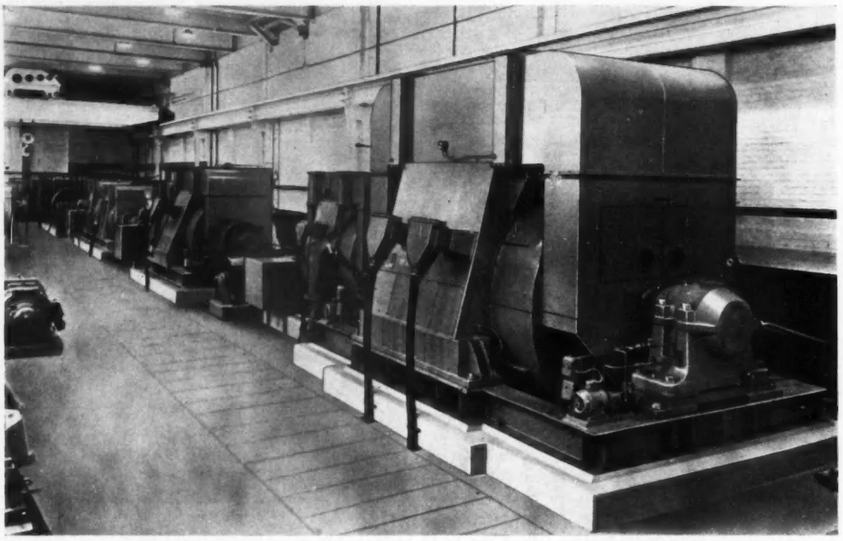


Fig. 1 Test machine room at Rugby works with 20-MVA motor-alternator set in the foreground.

TESTING LARGE ELECTRICAL MACHINES AND TRANSFORMERS

NEW PLANT INSTALLED AT B.T.H. RUGBY WORKS

The tests which, with few exceptions, are carried out on electrical apparatus before it leaves the works have several purposes: to prove the soundness of the design and manufacture, to expose any minor weaknesses, to satisfy the customer that performance guarantees are being met, and to enable final adjustments (for instance, to commutating poles) to be made. There is, however, an additional reason which is vital for both customer and manufacturer. This is to make accurate experimental measurements – frequently far in excess of the requirements of the customer or the specification. With large apparatus particularly, it is only on such accurate data collected during testing that advances in design can be based.

Modern machines and transformers are, however, so large that, except when two similar sets can be operated "back-to-back," it is not practicable either to supply the driving power or to absorb the output which would be produced during a full-load test. Even to circulate full-load current in the short-circuited windings of a transformer requires a supply of about a fifth of the rated kilovoltamperes; and a greater capacity is needed for heat runs. The same applies to large alternating-current machines. To overcome these difficulties the British Thomson-Houston Company, Limited, recently decided to install at their Rugby works a central test generating plant of substantial capacity, both for alternating and direct current. This plant has been so arranged that extension will be facilitated. It is also possible for the output to be used at various places in the works, other than in the new heavy-plant factory, where the test plant is installed.

GENERATING EQUIPMENT

The equipment of this new test plant consists of two main direct-current generators of advanced design. Each of these sets is rated at 700 volts, 2,400 amperes when running at 1,500 r.p.m., and is driven by a 2,000-kW alternating-current synchronous motor. The output of these machines, and that of a number of smaller auxiliary sets, is being used chiefly for testing large direct-current motors and alternators driven from test-plant motors in the heavy-plant factory. It is also employed, however, for supplying the driving motor of the new overspeed test, a description of which we published on page 267, *ante*. The two generators can be used singly, in series or in parallel.

The alternating-current generating plant has to meet the somewhat conflicting requirements of simultaneous availability in different places and of occasional large demands in any one spot. It has therefore been subdivided. Alternators with outputs of 20, 5 and 1 MVA were first installed, each of which is driven by a synchronous motor. A second 5-MVA alternator is being installed and provision has also been made for one of 10 MVA. A view of the machine room with the 20-MVA set in the foreground is given in Fig. 1. All three machines generate at 12 kV and have similar characteristics, so that while they are normally used independently, they can, when occasion demands, be connected in parallel. Using the motor of one of the direct-current generators as a synchronous condenser has already enabled an output of 28 MVA to be produced for testing 120-MVA, 275/132-kV transformers for the British Electricity Authority.

OPERATING CONDITIONS

The success of such parallel operation is dependent on two conditions. In the first place, the electrical "line-up" between the motor and alternator must be correct in each case in order that the load sharing shall be satisfactory. In the second, the excitation system has to be such that the alternator voltage control is the same, irrespective either of the number of machines in parallel or the distance of the control point. This is achieved by the use of auxiliary amplidyne exciters, the control fields of which are placed in series when their parent alternators are connected in parallel.

This complex layout, with its varied output, is, however, simple in operation and supplies from it are available in the heavy-plant factory, in the generator factory, in the turbine factory, and in the motor-compressor test house, which is a third of a mile away. At each place full control of alternator voltage, switching, and protection can be exercised, or, if the two direct-current generators are used as a Ward Leonard system, of the frequency. Interlocking for safety and fault protection have been provided on an extensive scale. The selection of any one, or several, alternator outputs for any test-station is accomplished by a simple switching operation. A central control room provides the test staff with equipment which gives a complete picture and over-riding control of the output of the plant on the miniature control board, illustrated in Fig. 2.

CONTROL OF HEAT DISSIPATION

Among the many special points of interest in this plant is the unusual enclosure of the alternators and motors. Each machine has a closed-circuit ventilating system with water coolers. The bearings are also water-cooled. By this means it has not only been possible to overcome the problem of heat dissipation in a limited enclosure, but very little noise is emitted. This feature is valuable when transformers are being tested in an adjacent area. Again, starting the alternator sets presents difficulties, but these have been overcome by providing one alternating-current and one direct-current set only with pony-motor starting. All the other sets are started on variable voltage, usually from the alternating-current set, before being synchronised on to the main incoming 12-kV line. The synchronous motors are considerably

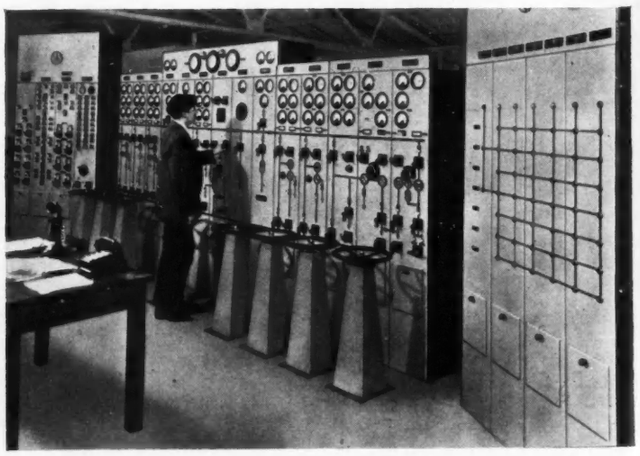


Fig. 2 In the test plant control room, the miniature switchboard provides a complete picture of the output of the plant at any time. From this board, an over-riding control can be exercised if necessary.

smaller than the alternators, since the kilowatts are much less than the kilovoltamperes.

TRANSFORMER TESTING

For testing transformers, provision has to be made for certain requirements which do not exist in machine testing. These are mostly concerned with high voltages. Every transformer has to be subjected to an over-voltage test at a frequency which will prevent saturation of its core. The supply for this, which is channelled through the system described above, is obtained from a special 250-cycle alternator which is rated at 4,000 kVA for short periods. The measurement of the induced voltage is made with a direct-reading peak and root-mean-square voltmeter rated at 900 kV and made by Haefely, of Switzerland. A one-metre sphere-gap provides protection and a check. Now that earthed-neutral systems are almost universal, separate-source high-voltage tests above 100 kV are unusual, but must not be entirely eliminated. A set of three transformers, each rated at 350 kV and capable of cascaded operation has therefore been installed to give 1,000 kV root-mean-square at 50 cycles. Other plant transformers of various ratings, have been provided which are designed to match the demands of the machines and transformers to the test alternators. The largest of these has a capacity of 30 MVA.

Current and voltage transformers of very high standard have been designed to enable measurements to be made at low power factors without corrections. Low power-factor polyphase wattmeters are also provided both for the transformers and for the alternators when the latter are being tested as synchronous motors. For machine testing, enclosed houses which contain both the instruments and controls have been built adjacent to the test stations so that decisions can be made in a quieter atmosphere than is usual in heavy machine testing.

Fig. 1 Holes for the strings are drilled on this machine. It is pneumatically operated and drills all the holes in four operations.

THE PRODUCTION OF TENNIS RACKETS

The Waltham Abbey factory of the Dunlop Sports Company, Limited, produces rackets for tennis, badminton and squash at the rate of about 5,000 per week. This is ten times the number that were being made when the company took over the premises in 1927. Of the number now being made, 60 per cent. are exported. At this factory, research work is continually being carried out and synthetic strings have now been produced which resemble the best quality natural gut so closely, both in performance and appearance, that they can only be distinguished by very careful examination. The manufacture and properties of these new strings are described in an article on the next page.

WOODS USED IN CONSTRUCTION

A modern laminated type of tennis racket is made up of 27 different pieces and at least three different woods. The bow is built up from strips of ash, birch or beech and is edged with hickory for extra strength. Wedges, where the strips of the bow join the handle, are of mahogany or sycamore, and the handle itself is usually of obechi, or, very rarely, of gaboon.

The logs are cut into lengths of approximately 5 ft. and are put into a steaming tank for 36 hours. The steam penetrates the centre of the log, softening the timber, giving a smoother cut, and making the bark easier to remove. The log is then placed on a rotary peeling machine where it is rotated against a fixed knife, converting the log into one continuous sheet of veneer. Veneers can be cut from 0·005 in. to $\frac{1}{16}$ in. thick. This method eliminates waste in cutting due to sawdust.

After peeling, the damp veneer is passed through a drying machine in which a number of steam-heated platens alternately grip and release the veneer as it is fed through by rollers. This drying operation takes between five and ten minutes, depending on the thickness of the veneer, and the speed of the machine can be controlled to give a final moisture content of 10 per cent. In order to prevent stresses when the components are assembled into tennis frames it is important that all the timber used is dried to this figure.

Small pieces of veneer or plywood are built up into larger units on a scarf-jointing machine, the joints formed being just as strong as the original timber. In this way the waste of material merely because it is undersized is avoided. After all suitable veneer has been directed to tennis racket production, small or second-grade pieces are converted into plywood for various purposes. Narrow pieces can be built up on an edge-jointer or by stapling. Plywood is made into packing discs for Fort Dunlop, dartboard backing boards, play-bats and table-tennis bats.

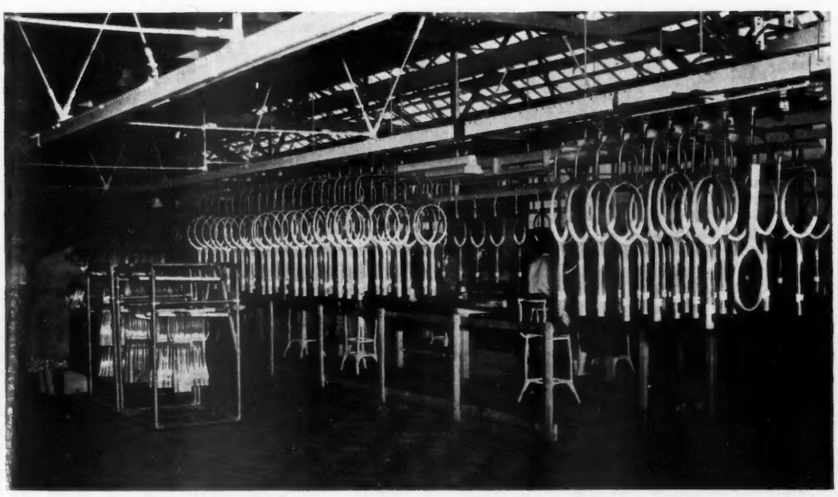


Fig. 2 Hung in groups of three on a conveyor, the frames pass through the polishing and spraying shops. Electrostatic spraying machines are used, the moisture in the wood being sufficient to act as a conductor.

ASSEMBLING THE FRAME

The strips forming the frame of the racket are glued together and interleaved with" Vellumoid " to provide strength to resist the tearing action of the strings. The strips, which are wide enough to make two rackets, are bent round a frame and clamped while the glue sets. Then the handle is glued in position, and for this a high-frequency heating plant is used. A special synthetic resin glue was developed by the company for this application. The next operation is to machine one face smooth and then to split the assembly into two rackets by cutting them in a sawing machine. (Badminton rackets, being narrower, are made in threes.)

Drilling of the holes for the strings is carried out in an automatic machine which drills all the holes in four operations. The machine is illustrated above. It is pneumatically operated, but a later model is driven by electricity; each drill has its own electric motor and is driven through a flexible shaft. Another motor drives the cams which move the drill heads and the series of operations is carried out when a starting button is pressed.

After being machined fairly closely to size, the rackets are finished by hand. This is a highly-skilled process, and the operators even make their own tools for the work.

POLISHING AND SPRAYING

The completed frames and handles are carried by a conveyor system through the polishing department illustrated on the left. Here transfer decorations are applied and the rackets polished prior to being lacquered. Those parts which are not to be sprayed are covered with paper or tape before the rackets are hung on the conveyor which takes them to the spraying plant. Each hanger takes three rackets and holds them apart during the time that the transfer decorations are particularly subject to damage.

Spraying is carried out in a Ransburg No. 2 machine, which has reduced time and waste. A stove-drying lacquer is used as this gives the best atomisation. The Ransburg machines use an electrostatic process which effects great

economy in the use of lacquer. Atomisation is carried out by forcing the lacquer into rotating bells, from the periphery of which it is flung forwards and outwards towards the line of passing rackets. The bells are electrostatically charged to 100,000 volts while the racket frames are earthed through the conveyor. At this voltage the moisture content of the wood provides sufficient conduction and about 95 per cent. of the lacquer settles on the frames. To give even distribution, there is an atomising bell on each side. After spraying, the rackets are partly air-dried before going into the oven.

STRINGING AND BALANCING

During stringing, the racket head is clamped on a table and the strings are threaded by hand. Pneumatic cylinders supply the force to tension the strings, and a maximum tension of 85 lb. is available. In this way distortion of the frame is reduced. The handles then have the grips applied – either leather strip, or rubber moulding – and the complete racket is removed for balancing. Laid on knife-edges, weight is added to or subtracted from the handle by inserting lead in a hole in the handle or drilling the hole deeper, so that the point of balance shall come at the right place. A final inspection completes the operations.

★ ★ ★

STRINGS FOR TENNIS RACKETS

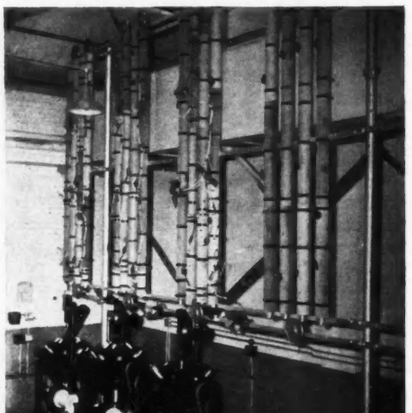
Synthetic Gut Gives Increased Strength and Resistance to Moisture and Abrasion

Research carried out by the Dunlop Sports Company, at their Waltham Abbey factory has yielded a synthetic string for tennis rackets which has superior properties to natural gut and can be produced more cheaply. Known as "DuroLastek," these strings have been tried out experimentally during the past season, often without the user's knowledge, and the substitution has never been detected. Over 4,000 rackets strung with DuroLastek have been in use.

The aim of the company was to produce a string which would reproduce the action of natural gut as nearly as possible, and which would not suffer from some of its defects. One of the latter is poor resistance to moisture; whereas natural gut collapses when it becomes moist DuroLastek can be soaked indefinitely and is fit for play as soon as the surface moisture evaporates. This is because, being made of nylon, the strings are virtually non-absorbent.

The illustration shows the machines used in the manufacture. A central nylon core has either one or two layers of nylon or Terylene filaments wrapped helically around it. An adhesive is applied during the wrapping to make what is virtually a single string. From the machines the string passes through the columns which can be seen in the illustration, where the adhesive is dried. Emerging from the bottom of the last one, the DuroLastek string is wound on drums and is then ready for use.

An extensive series of tests has been carried out to make comparisons between various materials that have been used for strings. These show that, with a tensile strength of 53,000 lb. per square inch, DuroLastek is considerably stronger than the best gut and slightly stronger than a single thread of nylon. Its resistance to abrasion is over five times as great as natural gut and the coefficient of friction about 4 per cent. higher. It is completely unaffected by moisture.



A central core of nylon is wrapped with layers of nylon or Terylene to give a string which has the same characteristics as natural gut. The layers are bound with an adhesive which is set in the heated columns above the machines.

On an endurance testing machine, a ball was struck 140,000 times, which is said to be equivalent to a life of between five and ten years. The strings were apparently still in excellent condition at the end. Measurements have been made with an oscilloscope to find out the stresses involved in the racket frame when using both DuroLastek and natural gut, and no significant difference could be detected. Nor was there any appreciable difference in the time during which the ball was in contact with the racket. The "feel" of a racket strung with this synthetic material is practically indistinguishable from that when natural gut is used.

★ ★ ★

LAUNCHES AND TRIAL TRIPS

M.S. "RAMBLER ROSE."—Single-screw cargo vessel, built and engined by John Lewis and Sons, Ltd., Aberdeen, for Hughes Holden Shipping, Ltd., Swansea. Main dimensions: 225 ft. between perpendiculars by 36 ft. 6 in. by 15 ft. 9 in. to upper deck; deadweight capacity, 1,650 tons on a mean draught of 15 ft. 3 in. Lewis-Doxford three-cylinder opposed-piston oil engine, developing 1,100 b.h.p. at 145 r.p.m. Trial trip, July 28.

M.S. "TROMAAS."—Single-screw oil tanker, built and engined by Eriksbergs Mek. Vertstads Aktiebolag, Gothenburg, Sweden, for Mr. Arnt J. Mörland, Arendal, Norway. Main dimensions: 526 ft. between perpendiculars by 69 ft. 9 in. by 39 ft. 3 in.; deadweight capacity, about 18,200 tons on a draught of 30 ft. 5 in.; oil-cargo capacity, about 860,000 cub. ft.; dry-cargo capacity, 30,000 cub. ft. B. & W. nine-cylinder single-acting two-stroke Diesel engine, developing 9,000 i.h.p. Speed, 15¼ knots, fully loaded. Launch, August 12.

M.S. "BRITISH CHANCELLOR."—Single-screw oil tanker, built by the Blythswood Shipbuilding Co., Ltd., Scotstoun, Glasgow, for the British Tanker Co., Ltd., London, E.C.2. Main dimensions: 515 ft. between perpendiculars by 69 ft. 6 in. by 37 ft. 6 in.; deadweight capacity, 16,110 tons. Barclay Curle-Doxford six-cylinder two-stroke opposed-piston oil engine, developing 6,900 b.h.p., constructed by Barclay, Curle & Co., Ltd., Whiteinch, Glasgow. Trial speed, 15½ knots, fully loaded. Trial trip, August 17.

S.S. "SOUTHERN CROSS."—Twin-screw passenger vessel, built and engined by Harland and Wolff, Ltd., Belfast, for Shaw Savill and Albion Co., Ltd., London, E.C.3. Main dimensions: 560 ft. between perpendiculars by 78 ft. by 45 ft. 3 in.; gross tonnage, about 20,500. Double-reduction geared steam turbines, developing 20,000 s.h.p. at 120 r.p.m., sufficient to provide a speed of 20 knots. Steam supplied by three Yarrow-type oil-fired boilers. Launch, August 17. See ENGINEERING, August 27, pages 258 and 260.

M.S. "VASSILIKI."—Single-screw oil tanker, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for the Nueva Vista Compania Naviera S.A., Panama. Main dimensions: 496 ft. between perpendiculars by 67 ft. 6 in. by 36 ft. 5 in.; deadweight capacity, 16,250 tons on a draught of 29 ft. 1¼ in.; oil-tank capacity, about 15,500 tons. Hawthorn-Doxford five-cylinder single-acting two-stroke opposed-piston oil engine, developing 5,500 b.h.p. at 115 r.p.m., constructed by R. and W. Hawthorn, Leslie & Co., Ltd., Newcastle-upon-Tyne. Speed, about 14 knots. Launch, August 18.

M.S. "ACHERNAR."—Twin-screw mine-sweeper, built and engined by the Chantiers de Constructions Mécaniques de Normandie, Cherbourg, France, for the French Navy. Main dimensions: 151 ft. 11 in. overall by 27 ft. 10 in. by 7 ft. 6 in.; displacement, 425 tons. Two sets of free-piston gas generators driving gas turbines and developing 2,000 h.p. Speed, 15 knots. Launch, August 18.

M.S. "BRITISH SERGEANT."—Single-screw oil tanker, built and engined by Harland and Wolff, Ltd., Govan, Glasgow, for the British Tanker Co., Ltd., London, E.C.2. Main dimensions: 490 ft. between perpendiculars by 65 ft. by 36 ft.; deadweight capacity, 14,000 tons. Harland-B. and W. six-cylinder single-acting two-stroke opposed-piston Diesel engine. Trial trip, August 19.

S.S. "DAPHNE."—Single-screw cargo vessel, built by William Gray & Co., Ltd., West Hartlepool, for the Compañia Armadora Transoceanica S.A., London, E.C.3. Main dimensions: 431 ft. between perpendiculars by 57 ft. 6 in. by 38 ft. 3 in. to shelter deck; deadweight capacity, about 10,000 tons on a draught of 26 ft. 6½ in. Triple-expansion steam engine working in conjunction with a Bauer-Wach exhaust turbine, constructed by the Central Marine Engine Works of the shipbuilders. Steam supplied by three forced-draught oil-fired boilers. Service speed, 12 knots. Launch, August 20.

S.S. "R. B. WATERSTON."—Twin-screw tug, built and engined by Wm. Simons & Co., Ltd., Renfrew, for the South African Railways and Harbours Administration, Cape Town. Main dimensions: 155 ft. overall by 34 ft. by 17 ft. 6 in. Two independent triple-expansion surface-condensing steam engines. Steam supplied by four multitubular boilers. Speed, about 13 knots. Launch, August 21.

M.S. "MONS CALPE."—Twin-screw vessel for the carriage of 600 passengers, 70 motor cars, mail and cargo, built by the Ailsa Shipbuilding Co., Ltd., Troon, for the Gibraltar to Tangier service of the Bland Line, Gibraltar (Agents: Watts, Watts & Co., Ltd., London, E.C.2.) Main dimensions: 283 ft. overall by 48 ft. by 26 ft. to shelter deck; mean draught, 10 ft. 6 in.; gross tonnage 2,000. Two marine Diesel engines, together developing 2,620 b.h.p., constructed by British Polar Engines, Ltd., Glasgow. Speed, 16 knots. Trial trip, August 24.

M.S. "SPENCER NALL."—Single-screw tug, built by W. J. Yarwood and Sons, Ltd., Northwich, Cheshire, for the Geelong Harbour Trust Commissioners, Victoria, Australia. First of an order for two. Main dimensions: 104 ft. between perpendiculars by 29 ft. 1 in. by 13 ft. 3 in.; displacement, 475 tons; static pull, about 16½ tons; gross tonnage, 280. Two-stroke uni-directional Diesel engine developing 1,310 b.h.p. at 300 r.p.m., constructed by British Polar Engines Ltd., Glasgow. Free speed, about 11¾ knots. Launch, August 25.

H.M.S. "TIDERACE."—Fast replenishment oil tanker, built by Joseph L. Thompson and Sons, Ltd., Sunderland, for the Admiralty, London, S.W.1. Length, 550 ft. between perpendiculars by 71 ft. beam; deadweight capacity, 17,700 tons. Main propelling machinery constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Wallsend-on-Tyne. Launch, August 30.

H.M.S. "KEPPEL."—Anti-submarine frigate, built and engined by Yarrow & Co., Ltd., Scotstoun, Glasgow, for the Admiralty, London, S.W.1. Length, 310 ft. overall; beam, 33 ft. Armament comprises three Bofors guns and two three-barrelled anti-submarine mortars. Propulsion provided by a high-powered geared steam turbine. Launch, August 31.

S.S. "BRITISH SOVEREIGN."—Single-screw oil tanker, built by Vickers-Armstrongs Ltd., Barrow-in-Furness, for the British Tanker Co., Ltd., London, E.C.2. First of two sister ships. Main dimensions: 630 ft. between perpendiculars by 85 ft. 6 in. by 46 ft. 8 in.; deadweight capacity, 32,100 tons. Parsons double-reduction geared steam turbines of Pametrada design, developing 12,500 s.h.p. at 112 r.p.m. Speed, 14¾ knots. Launch, August 31.

DRAUGHT CONTROL EQUIPMENT

Dampers for Horizontal or Vertical Boiler Flues

Some time ago, a description was published (ENGINEERING, vol. 168, page 32, 1949) of "Metro-flex" draught control equipment for Lancashire boilers, made by Metropolitan Combustion Engineering, Limited, 47 Whitechapel High-street, London, E.1. This firm are now making equipment for controlling the draught in other types of boilers with either vertical or horizontal flues.

In Fig. 1 is shown a diagrammatic arrangement of a curtain-type damper for sealing large horizontal flues. Its main use is where a complete seal is required, as for example, for by-pass flues or for sectionalising a system, rather than for draught regulation. The curtain itself consists of two main parts, a metallic load-carrying section and the actual sealing curtain made of a fibrous heat-resisting mineral material. Additional stiffening to resist the air pressure is provided by cross-bars, attached to the metal curtain, which span the flue sections. The curtain is raised and lowered by metal tapes.

The sealing curtains are woven in standard width as required, and are therefore seamless. The whole weight is carried by a self-adjusting tension control as may be seen in Fig. 1. This assists in removing any risk of uneven stress or stretching of the curtain and helps to prolong the useful life. When the curtain is rolled up to open the flue, the roll is completely contained in the headgear chamber and a quadrant valve closes, preventing the ingress of soot or dust. In this way, all moving parts of the mechanism are protected. The operating mechanism is protected against over-running by limit switches, which are also shown in Fig. 1. Operation can be either by electric, hydraulic or hand power, as required.

When actual draught regulation is required, and also when the flues are vertical, the louvre-type damper shown in Fig. 2 can be used. With this type, sealing is effected by a metallic strip fixed round the edge of the louvre, which presses against a step on the framework. As the louvres are suspended from the top bearing, they are not liable to jam due to bearing misalignment or blockage. In horizontal flues a flue-dust ejector is fitted which operates in a similar manner to that used in conjunction with the Lancashire-boiler damper described in the previous article. The ejector door opens before the louvres, and the full force of the gases rushing through the small opening carries away any soot deposits and prevents them from impeding the movement of the louvres. Each louvre unit with its frame can be lifted clear of the mountings for cleaning or repair. All the operating mechanism is outside the flue passage and so can be reached without interfering with boiler operation. This type of damper can be used with any pressure differential, and with temperatures up to over 1,000 deg. F.

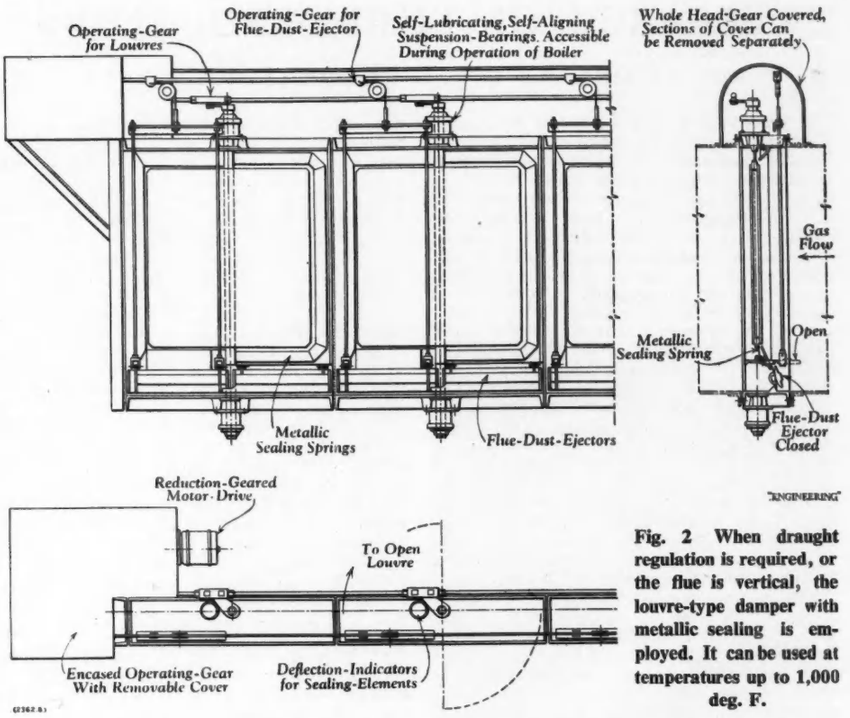


Fig. 2 When draught regulation is required, or the flue is vertical, the louvre-type damper with metallic sealing is employed. It can be used at temperatures up to 1,000 deg. F.

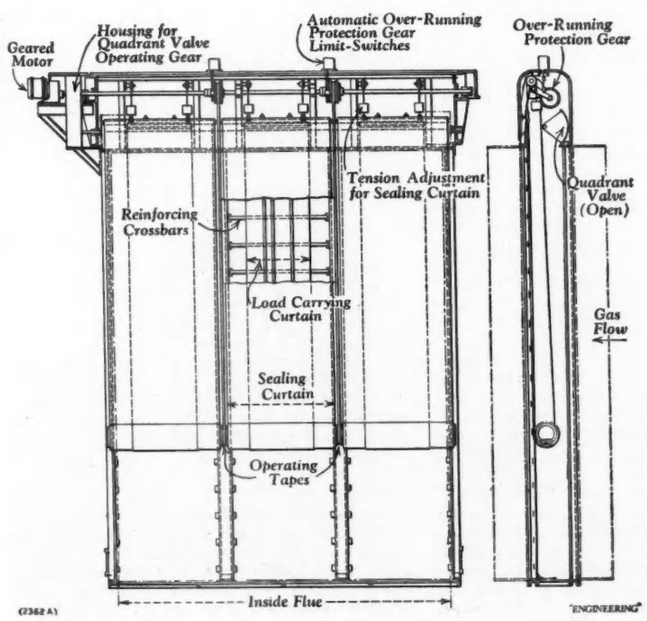


Fig. 1 The coiling curtain damper is mainly for sealing large horizontal flues. A quadrant valve prevents the ingress of soot when the curtain is fully rolled up.

SHUNTING LOCOMOTIVES FOR NEW ZEALAND

Delivery of 15 heavy-duty Diesel-mechanical shunting locomotives of 250 brake horse-power ordered by the New Zealand Government Railways from the Hunslet Engine Company, Limited, Jack-lane, Leeds, 10, has now begun.

The mechanical features are conventional, though a point of interest is that the 1¼-in. frame plates are inside the wheels despite the 3 ft. 6 in. gauge. Roller-bearing axleboxes are fitted having manganese-steel liners on the thrust faces and on the hornblocks. The wheels are 39¾ in. diameter and the wheelbase 10 ft. The length over buffer beams is 23 ft. 6½ in.

The power unit is a National vertical four-stroke engine from which the drive is taken through a friction clutch and a flexible coupling to a four-speed gearbox that also contains the reversing bevels. The final drive to the wheels is through a jackshaft and rods. The change-speed gears are of the internal-tooth type and have pre-selective compressed-air operation; emergency pedals fitted in the cab facilitate gear changing should the air supply fail.

The top track speeds in each of the four gear steps are 4¾, 8¼, 14¾ and 25½ m.p.h., and the corresponding rail tractive effects are 16,800, 9,630, 5,400 and 3,100 lb. These permit a 900-ton train to start and haul along the level in bottom gear, and a 240-ton train to do likewise up a 1 in 50 incline. The weight of the locomotive with all supplies is 30 tons.

* * *

DRAKELOW "B" POWER STATION APPROVED

The British Electricity Authority has received the consent of the Minister of Fuel and Power to the construction of a new section of the Drakelow power station, near Burton-on-Trent. It will be known as Drakelow "B."

The installation will include four 860,000-lb. boilers, each of which will supply a 120-MW generating set and four 3,820,000-gallon cooling towers. As the ultimate capacity of the "A" station is designed to be 240 MW, this will bring the total capacity of the site up to 720 MW.

RESEARCH ON SEMI-CONDUCTORS

WORK AT G.E.C. LABORATORIES

The recently-opened laboratories of the General Electric Company at Wembley are entirely devoted to concentrated research into all aspects of semi-conductors. These materials are not easily defined and have been variously described as "conducting electricity much less well than metals, but far better than insulators," "having electrical conductivity that increases with temperature" and "conducting electricity by reason of the impurities they contain." None of these definitions is perfect but together they give some idea of the properties that characterise semi-conductors. A description of the method of conduction of these materials was given in ENGINEERING, vol. 177, page 347 (1954).

The practical uses of these materials in the radio frequency ranges date back to the crystal detector which was extensively used in the earliest days of radio. The rebirth came in 1940 when the silicon crystal-diode was used as a mixer or frequency changer in almost all ultra-high-frequency radar equipment. The development of the germanium point-contact diode which is now used in communications and industrial control equipment came later.

Tremendous impetus was given to the study of semi-conductors by the discovery of the transistor in 1948. Bardeen and Brattain of the Bell Telephone Laboratories found that a triode amplifier could be made by arranging two point contacts close together on a small slab of germanium. While the full implications of this discovery have yet to be realised, its great importance was immediately apparent. About two years later there followed the discovery of the "*p-n*" junction rectifier which consists of a block of germanium, one part of which has an excess of *p*-type impurities (atoms that will accept electrons) and the other an excess of *n*-type impurities (atoms that will donate electrons). The potential barrier set up at the junction allows current to flow more easily in one direction than the other, giving a rectifying effect. Yet another device, the junction triode, was developed shortly afterwards. This can take many forms but is basically a sandwich in which a thin *n*-type layer separates two *p*-type regions, or vice versa. Such *p-n-p* or *n-p-n* triodes are capable of very efficient amplification. Group V metals provide the *n*-type impurities, while the *p*-type come from Group III.

The advantages of the new devices have been enumerated many times: long life, ruggedness, small size, low power consumption, etc. As the fundamental properties of this class of materials were investigated, it became clear that they would fulfil other purposes besides the rectification and amplification of electric current. For example, the point-contact diode can be designed so that the characteristics are sensitive to light, and its efficiency can be higher than that of other photo-sensitive devices. Discoveries like these indicate that other possibilities of equal significance may follow.

With these goals in mind, in 1952 the Company began building new laboratories in which this work could be accommodated. A large two-storey wing now supplements the space previously available. It includes departments whose work is devoted to: fundamentals, and the preparation of new semi-conducting materials; the preparation of materials with the properties required for use in the development of devices; the development and initial manufacture of new devices from existing semi-conductors; and device evaluation and circuit applications. Future plans provide for still further expansion in this field of research.

SEMI-CONDUCTORS IN USE

At a recent Press visit to the laboratories, there was a display of applications of semi-conductor devices. One showed a motor-cycle electrical circuit in which an alternating-current generator was used with two 10-ampere capacity junction rectifiers for battery charging. On the radio side there was a television line-amplifier with a centre frequency of 5 Mc/s and a band width of 3 Mc/s. This is shown in Fig. 1 with a ruler for comparison. It has a gain of 32 db. and a flat response to within $\frac{1}{2}$ db.

A totally different application is in an alarm circuit. The example shown was in connection with a Post Office telephone. A 20-kcs. transistor oscillator was mounted inside one of the gongs of a telephone hand set, and the output transmitted to the exchange. If the line to the exchange is cut or short circuited an alarm signal rings at the exchange. The circuit for this is shown in Fig. 2. No extra power is required to operate the system and it is not affected by ordinary use of the telephone.

Also being demonstrated was a 40-Mc/s transmitter, operated entirely by transistors, in which power for the oscillator was supplied by dipping steel and silver electrodes into a beaker of tap water. In the receiver, the phase-splitting transformer was eliminated by using an *n-p-n* junction transistor with a *p-n-p* one. With this system an efficiency of 75 per cent. has been obtained compared with a theoretical maximum for Class B of 78 per cent. The power gain is between 30 and 40.

To show the long life of transitors under normal operating conditions, a three-stage I.F. amplifier was exhibited using transistors throughout. This had been running continuously for over 7,000 hours without any appreciable change in performance. The unit was being automatically switched on and off five times an hour.

As an illustration of the photo-sensitive characteristics, a circuit had been arranged to ring an alarm whenever the light falling on the device exceeded a certain brilliance.

BASIC RESEARCH

Fundamental work on the properties of semi-conductors and the discovery of new ones is essential to the effort of the whole group. Research to find new semi-conducting materials is important for two purposes. Firstly, known semi-conductors such as germanium and silicon have physical properties (such as energy gap and charge carrier mobilities) which are not ideally balanced for use in some devices. The energy gap in a crystal structure may be defined as the amount of energy required to move an electron from a "donor" to an "acceptor." This may be so low that the movement occurs at room temperatures or it may require a considerable addition of heat. It is possible to envisage materials with more desirable properties and which would be neither so rare nor difficult to prepare as the semi-conductors used at present. Investigations are being made into the properties of such materials, including a new group of compounds with a crystal structure closely related to that of silicon and germanium. Known as chalcopyrite type materials, they have already been shown to possess some semi-conducting properties. For example, copper indium selenide ($CuInSe_2$) has shown point contact rectification with peak inverse voltages of about 400 volts.

Research into new materials also gives greater insight into the physical properties of semi-conductors. This field is relatively undeveloped but already many unusual effects, thermal, optical and magnetic, as well as electrical, have been discovered. Thermo-electric effects are well known in metals, in fact Peltier discovered 120 years ago that a junction of two dissimilar metals is cooled or heated when an electric current is passed across it. The magnitude of the effect is, however, very small if conventional metals are used, but some semi-conductors show a far more favourable combination of properties. The junction of the metal bismuth and the new semi-conductor bismuth telluride can be used to produce a temperature difference of 26 deg. C., and work on other materials is proceeding. This temperature difference of 26 deg. C. is obtained when a current of 5 amperes is passing with a dissipation of about $\frac{1}{4}$ watt.

Highly specialised apparatus is required for the research work, as usually the material investigated must not only be of particular purity but also, in order to study their properties adequately, in a perfect crystalline form. Minute traces of impurities or tiny defects in the crystal can radically alter the properties. In addition, almost all the starting materials of interest, such as arsenic, antimony, selenium and tellurium, are of a poisonous nature, although the final product is usually inert and harmless. Reactions have therefore to be carried out in special sealed containers or in high-velocity fume cupboards.

Fundamental studies have shown that a knowledge of the bulk properties is not sufficient for solving application problems. Every specimen is necessarily limited by a surface which, in an actual device, may be exposed to atmosphere or joined to another surface. The phenomena occurring at the surface of a semi-conductor are in fact radically different from those in the bulk material. Even with silicon and germanium, the present understanding of the surface phenomena is incomplete, and even less is known of the new semi-conductors.

The effect of various surface treatments on the electrical properties of these materials is being studied in the Laboratories. For example, the bombardment of a silicon surface with ions of various gases, accelerated by an applied potential of 30,000 volts, produces a drastic change in the electrical properties. A comparison between the current voltage characteristics of the treated and untreated materials shows that the ion bombardment has induced a permanent improvement in the rectifying effect.

PURE MATERIALS REQUIRED

The problems concerned in the preparation of suitable semi-conductor materials can perhaps best be illustrated by reference to germanium. This material is obtained from the dust and soot which collects in the flues of gasworks, particularly where coals from Northumberland and Durham are used. The semi-conductor is usually present as 0·5-1·0 per cent. by weight in the better flue-dusts and can now be obtained in quantities of the order of hundredweights.

After its extraction from the flue-dust, germanium is given elaborate chemical purification and is converted to the dioxide, which is then reduced by high temperature treatment with hydrogen. The metal thus obtained is fused and cast into an ingot, which has about one part of impurity to every ten million parts of germanium. Although very pure by chemical standards, this is still not good enough for semi-conductor devices.

Further purification is accomplished by means of a directional freezing technique known as zone refining. Only a small region of the ingot is melted at any one time, but the heat source is moved so that the molten zone also moves and slowly traverses the length of the bar. During the process, impurities, when at the junction of liquid and solid, concentrate preferentially in the liquid zone. By repeatedly traversing the bar, therefore, the impurities are ultimately swept to one end of the ingot, which is then sawn off. The process is shown in Fig. 3, where the ingot is being drawn through the heating coils. Eddy-current heating is used and the ingot passes five sets of coils in succession, becoming molten under each. The ingot is contained in a graphite crucible to which is attached a silica rod. An electric motor draws the rod along using a rack and pinion mechanism. At the completion of the refining, the impurities remaining only amount to about 1 part in 2,000,000,000.

Having obtained germanium of suitable purity, it then becomes necessary to prepare it in the form of a single crystal so as to give the required electrical properties. The metal is again melted, this time in a crucible, and a minute controlled amount of the element which determines the electrical properties is added.

A small " seed " of monocrystalline germanium is dipped into the molten mixture and, with very precise temperature control, the germanium begins to deposit in solid form on the " seed." By withdrawing the growing crystal at a predetermined rate, the entire contents of the crucible can be made to solidify in the form of a mono-crystalline ingot. Liquifaction is carried out under vacuum and the " seed " crystal is kept rotating at 60 r.p.m. The temperature of the melt is kept at 935 deg. C. $\pm$ 0·5 deg. C. Fig. 4 shows a grown crystal being withdrawn from the apparatus. A typical single crystal thus formed weighs about 400 gm.

After being tested to ensure that it has the required crystalline and electrical properties, the germanium ingot is then sawn and ground into the small plates used in the manufacture of crystal valves. The production of silicon can also be achieved by this single-crystal method.

SEMI-CONDUCTOR DEVICES

With the materials available, the device designer has to develop new circuit elements that will meet the needs of industry. The early work on the design and production of point-contact silicon crystal diodes for high-frequency mixer work has already been mentioned. Now, after a period in which the main emphasis has been on germanium devices, attention is again being focused on the use of silicon. Preliminary studies have indicated that silicon *p-n* junction diodes have several useful characteristics, including the ability to operate at considerably higher ambient temperatures than their germanium counterparts, very low inverse currents and a large rectification ratio between forward and reverse currents. To prepare silicon *p-n* junctions, donor and acceptor type electrodes are attached to a homogeneous silicon crystal of either type by heating the crystal and then bringing it into contact with metals to which it will alloy. A junction with *p*-type silicon, for instance, is made with a " donor " metal or an alloy containing a " donor " element such as antimony, phosphorus or arsenic. The junction is grown by deposition from the molten alloy when cooled and is situated between the unmelted silicon and the metal solid solution. An ohmic or base contact can be formed in the same way except that, on *p*-type silicon for example, an " acceptor " element such as aluminium or indium is used. By careful control of the heating and cooling cycle, and the selection of suitable metals and alloys, both the junction and the base contact can be formed simultaneously.

In one of the techniques being used, a gold-antimony alloy wire forms a *p-n* junction on *p*-type silicon and an aluminium wire provides the base contact. With *n*-type silicon these roles would be reversed, but no changes would be required in the manufacturing technique.

The manufacture of germanium *p-n* junction diodes proceeds rather differently. The junction is formed by fusing a bead of indium metal on to the carefully ground and etched surface of a wafer of single-crystal *n*-type germanium. The fusion is carried out in an electric furnace. As the temperature rises, a liquid indium-germanium alloy is formed, the percentage of germanium increasing with temperature. On controlled cooling to room temperature, the germanium re-crystallises together with enough indium to form a low-resistivity *p*-type layer as a continuation of the original crystal structure. There is thus an abrupt change in conductivity type at the junction between the original *n*-type and the recrystallised *p*-type materials. The resulting potential barrier leads to the well-known rectifier characteristic.

One of the rectifiers now being developed has a fairly massive copper base to remove heat dissipated in the device. When the *p-n* junction has been made, an enclosing copper cap is hermetically sealed to this base by a cold pressure welding technique. The success of this sealing method is such that these units have withstood long periods of storage under severe tropical conditions without change of characteristics.

Typical characteristics of one of the present designs of rectifier are 10 amperes at 0·5 volt, and 1 milliampere at -30 volts and 10 milliamperes at -160 volts. The development of a germanium rectifier to deliver large powers, having a much larger area and a highly-efficient cooling system to dissipate the heat, is in progress.

JUNCTION TRIODES

Just as the point-contact diode has a counterpart in the *p-n* junction diode, the point-contact triode has its junction counterparts, the *p-n-p* or *n-p-n* triodes. The three regions making the " sandwich " are not three separate crystals joined together, but a single continuous crystal lattice in which the conductivity type is changed abruptly by alternating the nature of the impurity atoms from one region to the next. Ohmic contacts, termed emitter, base and collector respectively, are joined to the three regions. The action of the device is such that the collector current is dependent on the emitter current and, since the impedance of the collector is much higher than that of the emitter, amplification of a signal is possible.

One method of making a junction triode is to grow a germanium crystal while varying the nature of the impurity atoms during growth to produce three regions with the correct spacing. Such a crystal is then sawn into small pieces for fabricating triodes, the junctions being known as " grown junctions." Alternatively, a method similar to that for germanium diodes can be used. A pellet of a suitable impurity metal is placed on a semi-conductor crystal of a certain conductivity type and the temperature raised. The pellet melts and then dissolves some of the germanium to form molten alloy. By reducing the temperature slowly, the dissolved material is redeposited on the crystal, but enough impurity atoms remain in solid solution to alter the conductivity type. If this process is carried out on the opposite faces of a thin slice of germanium, two thin layers of opposite conductivity type to the bulk of the crystal will have been formed, giving a triode configuration. Junctions obtained in this way are called " alloy junctions." This alloy technique is being used in the manufacture of triodes in the Laboratories, and the complete assembly is mounted in a hermetically-sealed container. These experimental units can be made with current gains up to 100 and collector voltage ratings up to 25 volts, and will operate at frequencies up to a few hundred kilocycles.

The performance of junction transistors has an upper frequency limit since a finite time is taken for charge carriers to migrate between emitter and collector. A higher frequency response would therefore be expected as a result of a reduction in the base layer thickness, and it is found that a reasonable amplifier gain at 10 megacycles is in fact obtained if this thickness is reduced to 0·0005 in. The required reduction is achieved by drilling a cavity in a germanium wafer 0·006 in. thick. A successful method of machining such a cavity, using a jet of electrolyte to etch the germanium, has now been developed to a stage where the depth of cavity is controllable to within 0 0001 in. This operation is shown in Fig. 6, in which the micro-manipulators used

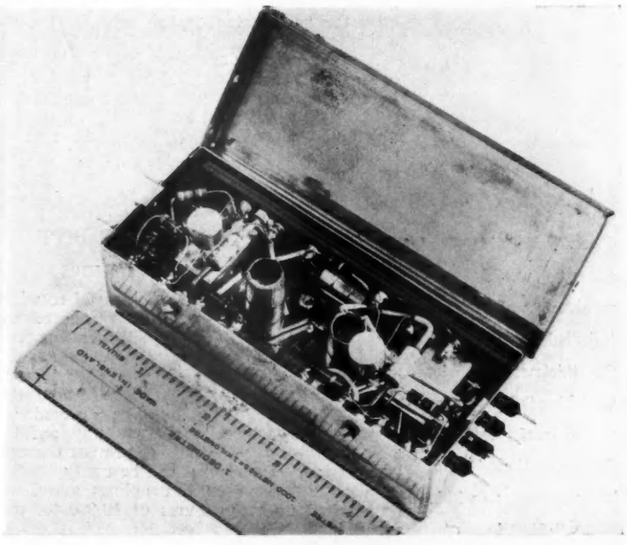


Fig. 1 5-megacycles television line amplifier with a band width of 3 megacycles. It incorporates two high-frequency point contact transistors and has a gain of 32 db.

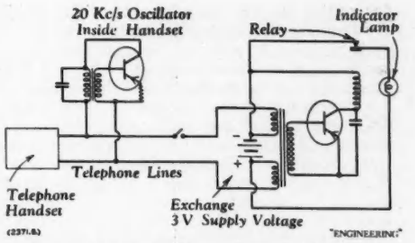


Fig. 2 Circuit diagram for an alarm system which operates if the telephone lines are cut or short circuited.

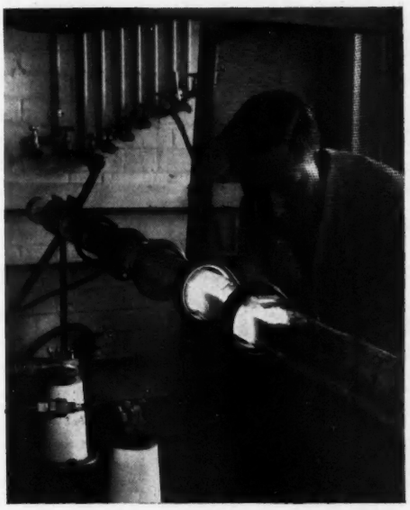


Fig. 3 Ingots of germanium are finally refined by being drawn past a series of induction heating coils. The impurities tend to collect in the molten part which moves along the ingot as it moves past the coils.

for setting up can also be seen. The etching fluid used in this process is potassium hydroxide. It is expelled at a fairly high velocity from a nickel tube which is negatively charged. The germanium wafer itself is positively charged and the interaction causes the etching to take place. With the use of the micro-manipulators it is possible to form a series of holes evenly spaced over the wafer. The high-frequency *p-n-p* germanium triode using such a drilled wafer has essentially the same construction as the lower frequency device. While the junctions are also prepared by the alloy method, it is more important in this case to prevent the junction from penetrating to any appreciable depth into the *n*-type germanium. An indium-germanium alloy therefore replaces the pure indium bead used previously, and the period and temperature of firing have to be rigorously controlled.

The performance of point-contact germanium triodes also falls off as frequency is raised owing to the effect of the emitter-collector spacing. Although this is small by ordinary standards (in one type, for instance, it is 0·003 in.) still smaller point spacings are required to improve the high-frequency response.

A point-contact germanium triode, recently designed in the Laboratories, will oscillate at frequencies as high as 100 megacycles. The problem of the close spacing required has been solved by using special assembly methods which allow distances as small as 0·0005 in. to be achieved. For amplifier use, point spacings less than 0·00075 in. have not so far proved useful because of the increasing effect of surface properties as spacing is reduced. This sets 10 megacycles as a reasonable manufacturing limit for amplifiers incorporating these devices. Owing to the deleterious effect of moisture on surface properties, the assembly of both diodes and triodes is carried out in a dry-box. After the point contacts have been set in place with micro-manipulators and fixed, the assembly is transferred to one of these boxes for sealing into its case. In these boxes the operator works through gloves which are sealed in, and a desiccant keeps the interior dry. The boxes are filled with nitrogen under slight pressure, so that only inert matter may be included in the case. Cold welding is necessary in the case of germanium units, but silicon can withstand a higher temperature, enabling a plastic to be used for sealing. In the machine shown in Fig. 5 the cold welding apparatus is incorporated and is operated by the assembler's foot.

FUTURE APPLICATIONS

It is already evident that the potential range of applications of semi-conductors is extremely wide. Most attention until now has been devoted to devices based on the electrical characteristics of semi-conducting materials, but it is likely that exploitation of their electromagnetic, photo-electric and thermoelectric properties will lead to new uses.

Fig. 4 After refining, the germanium is made to form a single crystal weighing about 400 grams. This is built up on a rotating "seed" crystal under carefully controlled temperature conditions.

The main uses of the present semi-conductor devices are in electronic equipments where small size, light weight, long life, ruggedness, reliability and low power consumption are important considerations. Much work is therefore being done in the design of suitable circuits for use with crystal valves and on the determination of the basic principles of their operation.

These are at present limited in their range of application by their maximum frequency of operation and their power output, but these limits are being rapidly extended by improvements in design and the development of new types. Experimental types have already been established which are capable of operating up to 10 or 20 megacycles as amplifiers and up to 100 megacycles as oscillators, while others working in the audio frequency range are capable of giving several watts output.

The most immediate and most significant of applications for crystal valves are likely to fall in the telecommunications field, where their special properties provide the solutions to existing problems in equipment design and open up quite new possibilities for the future. For example, crystal valves are likely in future to be found at many points in telephone systems – in exchanges, repeaters and subscribers' equipment. Many of the circuit problems involved are common also to computers and calculating machines, so that the establishment of a sound design for the elementary "bricks" of the system will lay a foundation for a far wider range of applications. Germanium diodes are already fulfilling a number of functions in present television receivers and other semi-conductor devices may be introduced gradually as they are developed.

Fig. 5 When sealing transistors into their cases, all moisture must be excluded. The cold-welding process is therefore carried out in a sealed dry-box, the press being controlled by the operator's foot.

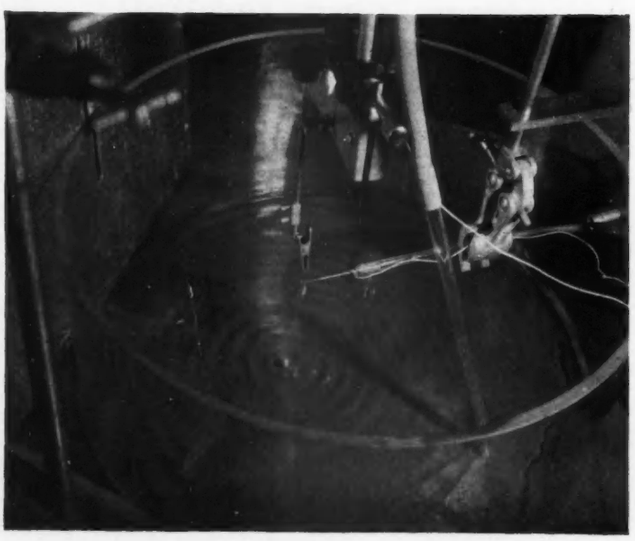


Fig. 6 For high-frequency work, germanium wafers are "drilled" to reduce the thickness. A jet of etching fluid impinges on the wafer and the depth of "cut" can be controlled to within 0·0001 in.

★ ★ ★

REDUCING HUMIDITY

Air-Drying Plant for Stores and Packing Shops

When equipment which deteriorates while damp has to be stored for any length of time, some degree of air-conditioning is required in the store. For this purpose, Birlec, Limited, Erdington, Birmingham, 24, have developed a range of air-dryers or de-humidifiers.

Known as "Lectrodryers," they use activated alumina as the drying agent. One of the advantages of this material is that the moisture it absorbs can be driven off by heat, and the material can then be used again. The Lectrodryers make use of this and incorporate a system of motor-driven distribution valves which control the air flows to the alumina beds. Heating for the re-activation cycle can be either by steam, electricity or gas. Control of the two latter is by thermostat, and safety devices are incorporated. Fans are built into the apparatus both for passing the dry air and for the re-activation cycle.

A range of standard sizes is available, with capacities up to about 15,000 cub. ft. per minute. In addition to being used for storage rooms, these dryers can control the humidity of packing shops and material stores where the cost of complete air-conditioning plant would not be justified.

★ ★ ★

REINFORCED PLASTIC PIPE

Suitable for High Pressures

A plastic tubing reinforced with metal to withstand high pressures has been introduced by Bowden (Engineers), Limited, Willesden Junction, London, N.W.10. It consists of an inner tube of a plastic selected to suit the fluid in use, covered with wire braiding to withstand the internal pressure. This may be covered by another sleeving, possibly fire resisting, and by a second layer of wire braid to prevent damage by abrasion. These pipes can be used with the standard Bowden swaged couplings and have been tested up to pressures of 10,000 lb. per square inch.

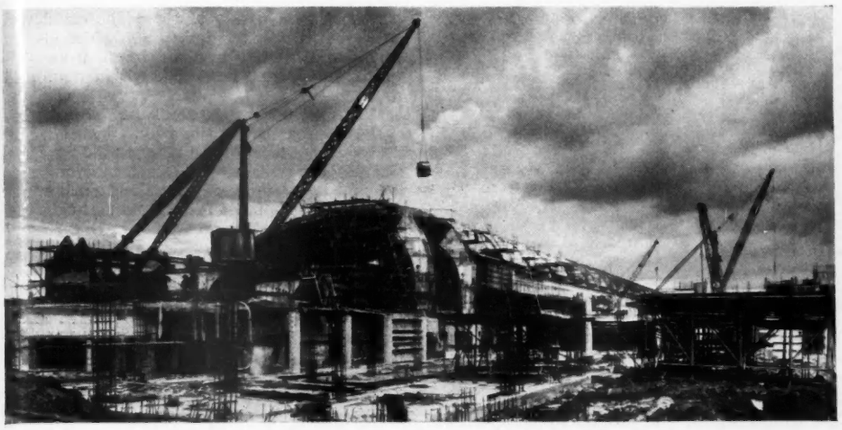


Fig. 1 The main hall in the course of construction. Using pre-cast concrete arches and shell roofs placed in situ, the main hall has a clear floor space 125 ft. wide by 800 ft. long.

TWO UNUSUAL PRESTRESSED-CONCRETE BUILDINGS

PRINTING WORKS FOR BANK OF ENGLAND

The new printing works at Debden, Essex, for the Bank of England includes two large prestressed-concrete buildings of unusual form and embodying many features of advanced design. The new buildings, on which construction began in June, 1953, and of which the main structures are now nearing completion, are destined ultimately to replace the Bank's existing printing works and will provide enlarged accommodation for modernised plant. The accommodation includes administrative and general offices, works space for various printing machinery, a chemists' section and ancillary works of various types, in addition to the requisite vaults and stores. It is the two main printing halls that are of particular interest and are described and illustrated herewith.

The site is about a quarter of a mile long by about 200 yards wide, and the main building, which includes the two printing halls, is about 800 ft. long with a maximum width of nearly 300 ft.; it is shown under construction in Fig. 1, above. A second building, comprising the canteen, recreation and committee rooms is separate from the main building, but is connected to it by a subway. The total floor space will be approximately 443,000 sq. ft.

The layout has been based largely upon the productive flow for the printing processes. The main building is for the most part on two levels so taking advantage of the sloping site. These levels are referred to as the upper ground floor and the lower ground floor; the former consists of production space and the latter contains heating and electrical plant, lavatories, cloakrooms, workshops, etc. The main production hall occupies the entire north side of the building; south of this hall is the general printing hall, storerooms and a smaller production hall. On the south elevation there are, in addition, three-, four- and five-storey blocks which contain office accommodation, research laboratories, etc., and the east elevation comprises similar multi-storey blocks above an underground boiler house.

The architects for the project are Messrs. Easton and Robertson, 53 Bedford-square, London, W.C.1, and the consulting engineers, Ove Arup and Partners, 8 Fitzroy-street, London, W.1. The principal contractors, responsible for all the concrete work, are Sir Robert McAlpine and Sons, Limited, 80 Park-lane, London, W.1.

The upper ground floor area is covered by three types of roof construction. The methods adopted for building these roofs, depending upon the repetition of the elements of the structures, largely determined the method of building throughout, because equipment required for their construction has also had to be employed for the rest of the job. In the case of the main production hall, the design of 22 identical bays of arched beams with concrete shell roofs has readily provided these elements. There is also repetition in other parts of the building as, for example, in a small production hall with five bays of arched beam and shell construction, and in another hall with balanced cantilever beam and shell construction of four free-standing bays.

THE MAIN HALL

For the main hall the problem was to cover a large space without internal supports and to provide daylight to this floor space by means of north-lights. An arched roof was chosen on aesthetic grounds, and a smooth curve selected to give the necessary clearances. In order to accommodate ventilation, heating, electrical and plumbing services it was decided to separate each pair of arches by a 3 ft. 6 in. gap: this has given 22 sets of identical structures, each consisting of two arches with north-light shells spanning between them. The arches were designed to be prestressed by the Freyssinet system. The form of the arch is shown in Fig. 2 and the services duct between the arches of adjacent structures can be discerned in Fig. 3 below.

The dimensions of the arch legs had to be kept to a minimum up to the level of the security gallery roof for reasons of planning. The tie force acting longitudinally at upper ground floor level on the arch produced high moments on this narrow section. It was therefore decided to use prestressing in order to reduce this tie force and, in consequence, the bending moments in the legs of the arch. Prestressing also helped to reduce the width required for the members and, as a

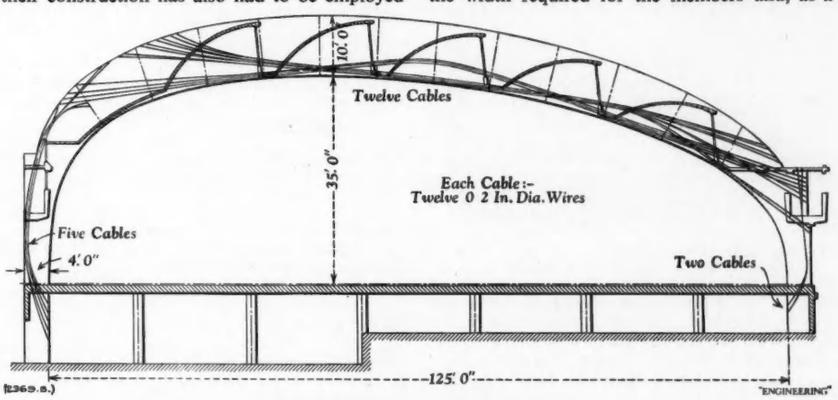


Fig. 2 Cross-section of main hall.

Fig. 3 Interior of main hall.

Figs. 2 and 3 Above the haunches the arches are of pre-cast sections about 10 ft. square, the double construction providing ample accommodation for the many services. Accurate location of the stressing cables was assisted by casting the sections flat on their sides. The assymetrical form of the hall has been designed to take full advantage of the north-light construction.

Fig. 4 Pre-cast north-light shells of the roof of the general printing hall.

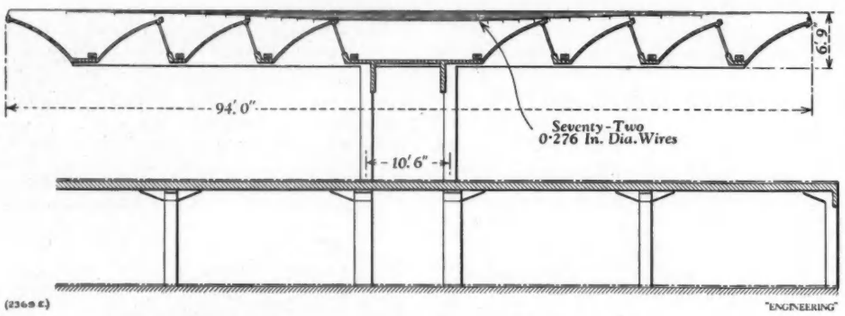


Fig. 5 Cross-section of the general printing hall.

Figs. 4 and 5 The general printing hall is located between the main hall and a multi-storey office block, and its balanced-cantilevered roof of 94-ft. span is supported solely by the central row of twin columns.

result, the deadweight which formed a large proportion of the total load.

It was decided to pre-cast the main arches of the roof of the main production hall in segments and to pour *in situ* the concrete of the shell roofs uniting these arches, so as to form bays 36 ft. long. The need for accuracy in the shape of the arches and identity from bay to bay was important, but so also was the quality of the surface finish of the concrete in members of slender sections in which prestressing cables are buried in close proximity. Of even greater importance was the accurate location of the stressing cables. The speed of construction was also very vital to this part of the work since any delay would have hampered the remainder of the work.

By pre-casting the centre section of the arched beams and making units of about 5 tons weight each, a major part of the problem was solved, since the accurate shape of the arch could be ensured by casting every arch on an identical bed. This bed was laid out flat, the concrete itself placed with maximum control around accurately placed duct tubes, and a good surface finish obtained. Moreover, these arched beams will carry fixings for mechanical equipment installed in the roof spaces and, by this method, the precise location of these fixings and other features has been ensured.

A 5-ton derrick with 120-ft. jib, to be seen in the foreground of Fig. 1, was installed to handle the precast elements, and also to assist in the remainder of the construction. A steel gantry has been used to erect the precast arched units. This 60-ton gantry is articulated in such a way that an accurate profile has been obtained by jacking at the main supports. The shutters for the shell roofs are each framed in one piece to span between main towers of the gantry. These shutters are raised and lowered in the gantry frame by a system of pulleys and winches and, once the main frame of the gantry is jacked to its correct alignment and profile, the shell roof shutters are raised to a fixed position and held in place by six bolts.

After the concrete of the shells, poured *in situ* from skips handled by the derrick, had hardened, the barrel shutters were easily lowered by the winches. After stressing, the gantry was also lowered by the jacks on to the bogies so that the whole gantry, together with all the formwork, could be moved on rails to the next bay.

The lower parts of the arched beams and galleries were cast *in situ*, and shutters in large units were used which could be handled by the derrick; all prestressing ducts were cast in. An exception to this is the fluted front of the galleries since, as this is to be a major decorative element in the design, it was pre-cast on a teak shutter so that a first-class finish could be ensured.

The upper ground floor, that is, the floor of the main hall, shown in Fig. 3, the general printing hall and the smaller production hall, is generally of flat slab construction. In the main hall, where columns could be fairly closely spaced (bay sizes 18 ft. by 19 ft.), there are no capitals. This helped the detailing of services, which will be fairly extensive under this floor. Bracket capitals have been used under the floor of the general printing hall where larger bays (24 ft. square) are required.

GENERAL PRINTING HALL

The roof of the general printing hall covers the space between the multi-storey blocks on the south elevation, and the structure of the main hall. It was necessary to provide an expansion joint at each side of this roof and a balanced-cantilever structure was therefore selected, making a complete break with the structure on each side. This building is illustrated in the accompanying Figs. 4 and 5. The cantilevers were prestressed to limit the deflection and to reduce the thickness of beam from that which would have been required in reinforced concrete.

Maximum use was made of the 5-ton derrick in the construction of this roof, which is 94 ft. wide. It consists of four free-standing bays, and each bay is made up of four cantilever beams spanned by a series of north-light shell roofs. Each shell is about 24 ft. long, so that each bay of three sets of shell roofs with cantilever supporting beams is 72 ft. long.

The shells were pre-cast and weigh about 5 tons each, while the beams were cast *in situ* using shutters in large sections which were handled by the derrick. The beams are nearly 7 ft. deep by 9 in. or 6 in. thick; they were cast *in situ* because the prestressing system adopted was completely exposed during construction, so that there was the minimum obstruction in the section of the beams and proper placing of the concrete to give good quality consolidation and surface finish was more readily attained.

The cantilever beams were prestressed on the Gifford-Udall-CCL system by a series of single wires assembled in 12 layers, one above the other, each layer of wires being longer than the one below it in such a way that the desired distribution of stress in the beam can be ensured; this is illustrated in Fig. 5. The anchorage of the wires was specially designed and consisted of a 1-in. thick metal plate buried and anchored in the concrete of the beams in such a way that it can take a load (in the case of the 9-in. thick beams) of about 60,000 lb.

When the beams were cast, and before stressing, the pre-cast shells, which were constructed so that they were about 1 in. shorter than the space between the beams, were lifted by the derrick and placed between the beams. The space between the ends of each shell and the face of the beam in which there was a $\frac{1}{4}$ in. recess was then packed with mortar. When all the shells in the 72-ft. bay were in position and the joints packed with mortar, the whole roof was prestressed in a transverse direction, that is to say, along the shells and through the beams, by six prestressing wires to each shell. When the shells had been prestressed and loading of the beams thus provided, the beams were also prestressed. This was done by working upwards from the shorter wires, layer by layer, until the longer upper wires were stressed.

It was necessary to devise a method of temporarily loading the ends of the cantilever, so that, as the stressing of the beams proceeded, there was no over-stressing of the concrete at the top of the beam in compression. In addition, it was necessary to concrete in the prestressing wires on top of the beam to protect them from the weather. Since this concrete filling, because it is not prestressed in the same way as the remainder of the beam, might crack due to differential movement with consequent exposure and corrosion of the wires, it was decided to load the beams in two stages. First, to load them sufficiently to ensure that the concrete was not over-compressed during stressing. Second, to induce deflection in the cantilevers before surrounding the prestressing wires with concrete, so that when this concrete matured, the release of the loads would result in an upward movement of the cantilever and a consequent compression in the concrete on the top of the beam.

This temporary loading was provided by a steel rod anchored by a stirrup to the underside of the ends of the cantilever, and joined to a short beam which itself was anchored to the heavy floor by means of bolts. One side of this short beam was bolted to a plate in the floor, and the other side joined to a similar plate by means of single wire prestressing. In this way, by prestressing the wire stage by stage, and shimming against the anchor, progressive loading could be given to the steel rod and therefore to the beam. This loading was measured both by reading the gauge of the stressing jack, and by strain-gauge readings on the rod. Loads up

to about 7 tons were quickly placed on the cantilever in this way.

FOUNDATIONS

The foundations are generally of the isolated pad type on brown clay which, at a depth of 7 ft. below original ground level, was capable of sustaining a load of 2 tons per sq. ft. Other work below ground consists of ducts of various sizes to accommodate heating and electrical services. These ducts are of reinforced concrete; the walls were precast in about 10-ft. lengths, generally 6 ft. 6 in. high, and jointed with 12 in. lengths of *in situ* concrete; they were placed with a mobile crane.

Formwork for the job, apart from the travelling gantry, was designed and made on the site. To give the required high quality of finish to the work resin-bonded ply has been widely used. The high cost of these purpose-made shutters made it necessary to obtain as much use from them as possible.

Practically the whole of the *in situ* part of the concrete has been cast in steel-pan formwork. In the case of the main machinery floors, which are from 12 in. to 15 in. thick and designed on the mushroom principle to give large areas of flat soffit surface, it was possible to fabricate forms on a framework so that they could travel in panels about 24 ft. long. This ensured the minimum of work in striking and fixing.

BOWATER'S PAPER MILL AT CALHOUN, TENNESSEE

BRITISH ENTERPRISE IN THE UNITED STATES

In a Weekly Survey note (August 20), we drew attention to the establishment by the Bowater Paper Corporation, Limited, Stratton-street, London, W.1, of pulp and paper mills at Calhoun on the Hiwasse River in Eastern Tennessee, where the organisation owns 200,000 acres of forest land from which the necessary raw material will be drawn. Apart from its technical interest, the project is of great economic importance, since the United States produces less than 20 per cent. of its newsprint requirements, the rest being imported.

An external view of the mill, which began operations in June, 1954, is given in Fig. 1. It has been designed on the most modern lines for an annual production of 130,000 tons of newsprint and 55,000 tons of unbleached or bleached kraft pulp. The latter will be exported to the mills of the Bowater Organisation in the United Kingdom for the manufacture of newsprint and of printing and packaging papers. On the other hand, the newsprint produced at Calhoun will be utilised in the United States, especially in the southern part of that country, thus obviating the present long hauls from Newfoundland and releasing some of the output of the Corner Brook mills for use in the north.

WOOD HANDLING AND PREPARATION

The raw material necessary for paper making is pinewood, of which 906 cords will be used a day. It is brought by river as well as by rail and road transport and is unloaded by cranes or rakes into a pit or on to a multi-chain feeder. In each case, it next passes to a rotary turntable, 60 ft. in diameter, where the different species are sorted and then dispatched down chutes to the barking drums by hydraulically operated remote-controlled blades.

Barking is carried out by the dry method in three suspended drums, each of which is 12 ft. in diameter and 45 ft. long. The bark is taken away by belt conveyors, while the stripped timber is carried by two cable conveyors to the centre of a storage pond, where it is dumped on to a turntable, 40 ft. in diameter. This pond, which can be seen in the foreground of Fig. 1, has a capacity of 30,000 cords, sufficient to supply the mill for six months, an arrangement which is necessary as pinewood deteriorates rapidly when stored in air.

The logs, which are stacked in a semi-circular pile, are removed from the pond as required by cranes, which discharge them on to turntables from which they are delivered on to the appropriate cable conveyor. These conveyors, which are arranged as washing flumes, so that the residual grit is removed, unload on to a further turntable. The logs that are suitable for mechanical pulp are then discharged under a butting saw. They then pass down a chute into a 1,900-ft. long flume at the end of which they are fed by a conveyor into the grinders. Wood, which is only suitable for chemical pulp, is, on the other hand, discharged from the turntables into a chipper and thence through a surge bin to a pair of screens. The oversize chips are returned from these screens to the chipper for further treatment, while the fines, together with the dust from the butting saw and the dry bark, are sent to the power plant for combustion in a refuse boiler. The remaining chips are taken by other conveyors to three silos, whence they are removed by rotary plate feeders to the digesters.

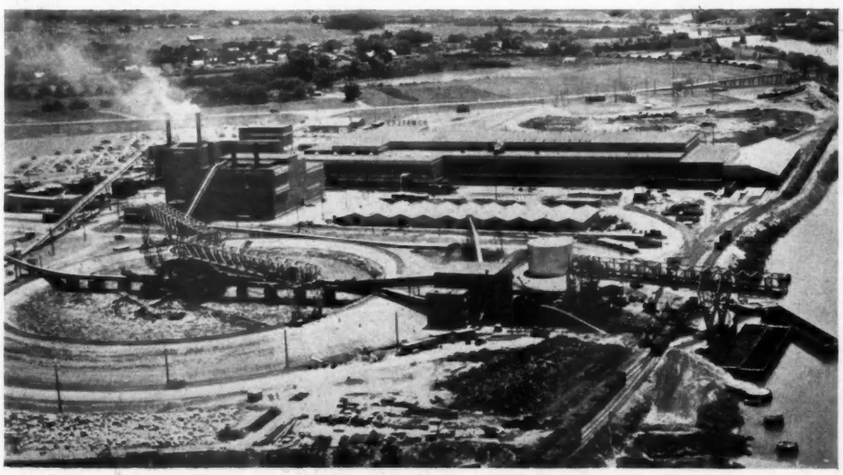


Fig. 1 The Tennessee paper mills of the Bowater Paper Corporation, showing log-handling plant and the storage pond.

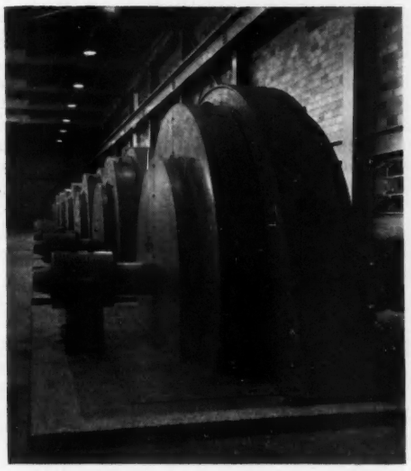


Fig. 2 Eight 4,500-h.p. synchronous motors for driving the grinders in the Calhoun mill, Tennessee.

Fig. 3 View of a washer for treating chemical pulp.

DIGESTER PLANT

These digesters, of which there are five, are used for the production of raw kraft, and discharge to a blow tank. The blow steam is subsequently used for heating water, while the relief steam from the digesters themselves is passed through separators and condensers into decanters, where turpentine is recovered.

The stock from the blow tank is pumped into pre-knotters and three vacuum-type washers, from the last of which it is delivered to a storage tank. This tank, which has a capacity of 100 tons, is equipped with agitators and dilution nozzles to ensure the right consistency of the contents before they are pumped through two primary centrifugal screens. The stock retained on these screens is discharged by gravity to two thickeners and thence into a screened stock chest. On the other hand, the

stock rejected by the primary screens is discharged into a tank, whence it is pumped to a secondary screen. The material retained on this screen is, in turn, returned to the stock chest or to the pulp dryer. The tailings from the secondary screens are passed to a second tank, whence they are pumped through a magnetic separator, drainer and disc refiner to the primary rejects tank for re-circulation and re-screening. The liquor and soap from the washers are recovered in a further series of tanks.

BLEACHING PLANT

The pulp which is to be bleached is pumped from the screened stock chest through a chlorinating tower and thence through a washer and mixer to a caustic extraction tower, where it is diluted and delivered at high consistency to a hypochlorite tower. At the bottom of this last tower it is again diluted and pumped to a final washer, shown in Fig. 3, on page 317, whence it passes through a consistency regulator into a storage tank. It can be pumped from this tank either to the newsprint mill or to the pulp drier, as desired.

The upper part of the building containing this plant is totally enclosed, pressurised to eliminate corrosion and equipped with fans for removing the vapour from the washers and towers. The instruments, motors and control apparatus, which are enclosed by glazed partitions, are swept with filtered air. Effluent from the chlorination and caustic stages is carried to a foam tower, which also receives the fumes and foam from the seal pits.

PULP DRYER

Both the unbleached and bleached pulp is dried in a wet machine of the two-press type, from where it passes to a hot-air dryer. These two machines are driven by direct-current motors, which are supplied from a single motor-generator, those in the different sections being synchronised. After drying, the pulp is taken to a cutter which is also driven by a direct-current motor. Here it is trimmed into five 31¼ by 25½ in. sheets and three 47-in. by 53-in. wrappers, and ejected on to a table in the form of vertical stacks. This table descends to its bottom position when the requisite number of sheets has been accumulated on it and then discharges them on to a conveyor before it returns to its original position. The stacks are then delivered by conveyors to a baling press from which they pass to a store with a minimum capacity of 800 tons.

PAPER-MAKING EQUIPMENT

The logs for paper making are delivered from a water flume conveyor on to inclined chain conveyors which, in turn, discharge them on to an apron conveyor and thence to the grinders. Eight grinders are at present installed, each being driven by a 4,500-h.p. synchronous motor and being fitted with governors and hydraulic control equipment. A view of these motors is given in Fig. 2. From the grinders, the pulp passes through a series of screens and Dirtec units, which remove the shives and dirt, into thickeners before being passed to a store.

The bleached kraft is refined in four jordans, and after the cleaning is supplied through a battery of six screens to one or other of the two papers machines which are at present installed.

The paper-making machines, a view of one of which is given in Fig. 4, are designed to run at speeds up to 2,000 ft. per minute and to produce newsprint 252 in. wide. The wire with which they are equipped is 116 ft. long and is complete with table rolls, suction boxes and save-alls for separating the drainage from the shower water.

The press section consists of an automatic suction pick-up roll, a suction transfer press, wringer roll and two straight-through suction presses. The dryer section is made up of 55 paper dryers, 60 in. in diameter, and eleven felt dryers, also 60 in. in diameter, which are divided into four sections. The calender stack is of the open type with eight rolls. The reel is of the heavy-duty pattern, while the winders are of high-speed design with a shaft puller and roll lowering table. Operation is by electric sectional drives. Vacuum pumps are provided for the couch roll, suction boxes, presses, transfer equipment and felt conditioners. The wire and couch pit are of special design, and wet "broke" from the couch flows directly into a chest in which breaker agitation equipment is installed. This chest also handles the press broke, which is delivered to it by a conveyor. A disintegrator is installed at the dry end of each machine for handling broke and winder "trim." Both machines are equipped with hood-and-felt drying systems and complete air make-up, heating and ventilating, and motor-cooling equipment has been installed, both in the stock preparation and machine rooms.

The rolls of newsprint are discharged from the winder on to conveyors which take them to an automatic wrapping machine. They then pass through scales to a storage space on the second floor from which they can be delivered to a shipping platform.

ELECTRICITY SUPPLY

All the machines in the mill are electrically driven and when in full operation the load will be about 37 MW, of which 20 MW will be required for wood grinding. Of this total, 20 MW will be obtained from generating plant installed in the mill itself, which will also supply the process steam, and 17 MW from the Tennessee Valley Authority. Normally, the two systems will operate in parallel, but they can be arranged so that the public supply is utilised independently in the grinding section, and the works plant in the rest of the mill. It will also be possible for the mill as a whole to be operated from the public supply, if one of the works units is out of service.

The steam-raising equipment includes two boilers, each with an output of 150,000 lb. per hour at a pressure of 875 lb. per square inch and a temperature of 825 deg. F. These will usually be fired by natural gas from a neighbouring main, although fuel oil can be employed during periods of gas shortage. Provision has also been made for employing pulverised coal. They will be automatically controlled when gas is used, but during oil firing they will be manually operated. A pressure controller, operated by the pressure in the main header is also fitted to enable these two boilers to produce the steam which is required in excess of that from the third and fourth boilers mentioned below.

The third boiler, which has an output of 125,000 lb. of steam per hour under the same conditions, is fired manually either by wood bark or, if one of the other boilers is out of action, by natural gas. A fourth, with an output of 123,200 lb. of steam per hour, is fired by solid waste from the chemical plant, which amounts to 950,000 lb. per day. It is equipped with both forced and induced-draught fans and pneumatically-operated soot blowers. The salt cake dust is recovered by electrostatic precipitators and

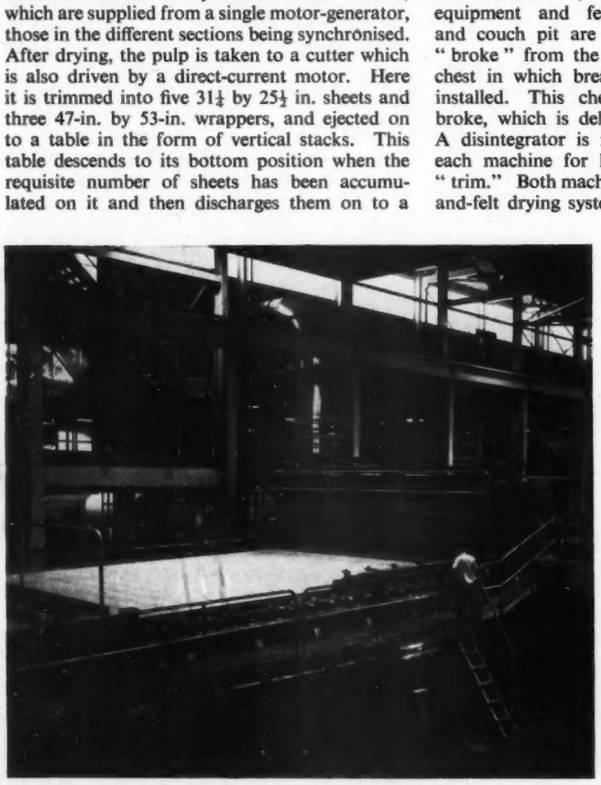


Fig. 4 One of the Fourdrinier newsprint machines in the Calhoun mill. This machine has a wire width of 252 in. and a speed of 2,000 ft. per min.

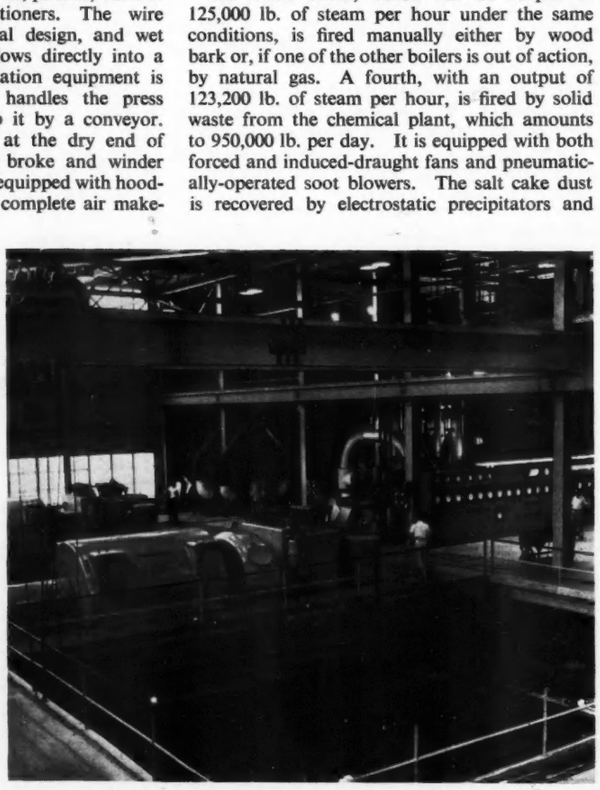


Fig. 5 Turbine room from which half of the electric power consumed in the mills is obtained.

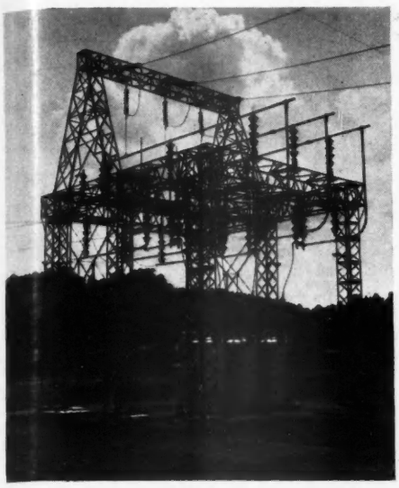


Fig. 6 Outdoor substation of the Tennessee Valley Authority, from which power is supplied to the mill.

dissolved in pans through which concentrated liquor is circulated.

These boilers supply two 10-MW turbines, which are illustrated in Fig. 5. A proportion of the steam from one of these sets is extracted at 50 lb. per square inch for process purposes, while the rest is exhausted to a condenser. Steam is extracted from the second machine at 150 lb. per square inch and at 50 lb. per square inch back pressure. The extracted steam at both pressures is fed into ranges for use in the works, de-superheaters being installed at the service points, which reduce its temperature to just above saturation. The 875-lb., 150-lb. and 50-lb. ranges are interconnected through reducing valves, so as to increase the flexibility of operation.

FEED HEATING SYSTEM

The condensate from the first turbine, as well as other hot water, is discharged to a storage tank to which make-up (amounting to between 20 and 50 per cent. of the total feed-water demand) is added. The water from this tank is pumped to a de-aerator, which is heated by steam at a pressure of 5 lb. per square inch. This steam is supplied through a reducing valve from the 50-lb. range. The water next passes through the feed pumps, which discharge it at a pressure of 1,080 lb. per square inch, to a second feed heater and thence to the boilers. This high-pressure heater is supplied with steam at a pressure of 50 lb. per square inch and raises the temperature of the feed water to 280 deg. F.

Three feed pumps, each of which has an output of 1,200 gallons per minute, are installed. One of these is driven both by a turbine and a motor, while the other two, which are intended as stand-bys only, are entirely electrically operated. Normally, the first pump is driven by the turbine but, as the steam supply is irregular, the motor, which is generally lightly loaded or floating on the shaft, is designed to pick up the load automatically when the pressure decreases below that required to maintain the full output.

The power obtained from the Tennessee Valley Authority's system is supplied at 13·8 kV and 60 cycles to two 15-MVA transformers which are installed in the outdoor substation illustrated in Fig. 6 and is thence transmitted to the grinder room for operating the 4,500-h.p. synchronous motors mentioned above. A supply is also given through two 750-kVA transformers at 460 volts to the auxiliary motors.

The output from the two 10-MW sets mentioned above is distributed at 13·8 kV to the wood yard, pulp mill, bleaching, stock preparation and machine rooms, where it is stepped down to 2·3 kV for supplying motors with capacities between 201 and 1,000 h.p. and to 460 volts for the smaller units. The 10-MW sets and the Tennessee Valley Authority's mains are interconnected through a synchronising bus-bar and are controlled from a central point.

Generally speaking, the motors installed in different parts of the mill are of a standard type. Those driving the grinders are, however, equipped with built-in air coolers, while those on the paper machines are of the enclosed separately-ventilated pattern and are equipped with electronically-controlled voltage regulators.

The necessary compressed air supply for the mill is obtained from two compressors, which operate at a pressure of about 110 lb. per square inch. In addition, a third compressor, which operates at 350 lb. per square inch, supplies air to the soot blowers on the recovery boiler. Air for instrumentation is obtained from further compressors of the "carbon-ring" type so that no oil is introduced into the system.

RECOVERY PLANT

The recovery plant includes a six-body sextuple-effect evaporator for dealing with the surplus black liquor from the kraft mill. The vapours from the sixth effect of this plant are condensed in a vertical surface condenser, while soap is removed from the liquor between the third and fourth effects by a mechanical skimmer. Dry solids in the black liquor are burnt in the recovery boiler mentioned above. The causticising plant, which is of conventional design, has a capacity of 30,200 cub. ft. per day of white liquor as well as 8 lb. per cubic foot of total alkali and 7 lb. per cubic foot of active alkali. The lime-reburning plant consists of a rotary lime kiln with a capacity of about 80 tons per day, limestone being used as make-up.

The raw water for the mill is obtained from the Hiwassee River. It is withdrawn at a place about 2½ miles above the site by three vertical submerged pumps, each of which has an output of 6,000 gallons per minute and delivered to a fabrication plant. It then passes to a concrete-lined reservoir with a capacity of 4 million gallons, the lower section of which is reserved for fire-protection purposes.

* * *

HEAT TREATING A 120-FT. FRACTIONATING COLUMN

A Temporary Furnace

The problem of stress relieving the central weld joining two halves of a high-pressure oil-fractionating column 120 ft. long by 44 in. diameter is discussed in report No. 566/53 issued recently by the East Midlands Gas Board and the Gas Council, 1, Grosvenor-place, London, S.W.1. The two 60-ft. sections were stress relieved in a furnace before joining them together, but there was no furnace in the area large enough to take the complete column, which, according to specification, was required to have all welds heat-treated in accordance with a code of practice issued jointly by the American Petroleum Institute and the American Society of Mechanical Engineers in 1943.

To carry out this task a brick duct was built around the lower side of the vessel, which was lying on its side, and the upper half surrounded by a sheet-metal duct so that the join was enclosed. When complete, the surrounding structure took the form of an annular chamber 15-in. wide into which hot gases were drawn from a combustion chamber by a high-speed axial fan and circulated around the outer surface of the vessel at high velocity. No. 600 and 400 Hypact burners were fitted in the combustion chamber, each separately controlled.

NOTICES OF MEETINGS

Incorporated Plant Engineers

LONDON
Open Discussion Meeting. London Branch. Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Tues., Sept. 7, 7 p.m.

BRISTOL
"Planning and Reconstruction in Bristol," by R. W. Jefford. Western Branch. Grand Hotel, Bristol. Wed., Sept. 15, 7.15 p.m.

DUNDEE
"Manufacture of Ball and Roller Bearings," with film, by W. N. Mills. Dundee Branch. Mathers Hotel, Dundee. Mon., Sept. 13, 7.30 p.m.

EDINBURGH
"Oil Firing of Steam Boilers," by J. R. Henshilwood. Edinburgh Branch. 25 Charlotte-square, Edinburgh. Tues., Sept. 7, 7 p.m.

GLASGOW
"Compressed Air in Industry," by H. Burnett. Glasgow Branch. Scottish Building Centre, 425-427 Sauchiehall-street, Glasgow. Wed., Sept. 15, 7 p.m.

MANCHESTER
Film: "Principles of Automatic Control." Manchester Branch. Engineers' Club, Albert-square, Manchester. Tues., Sept. 7, 7.15 p.m.

NEWCASTLE-UPON-TYNE
"The Engineering Application of Electro-Deposited Metals," by J. W. Oswald. North-East Branch. Roadway House Oxford-street, Newcastle-upon-Tyne. Thurs., Sept. 9, 7 p.m.

ROCHESTER
"Causes and Prevention of Steam-Plant Scale," by W. F. Gerrard. Kent Branch. Bull Hotel, Rochester. Wed., Sept. 15, 7 p.m.

Institute of Petroleum

LONDON
"The Application of Turbogrid Trays in the Petroleum Industry," by Dr. G. J. van den Berg. Wed., Sept. 8, 5.30 p.m.

Institute of Road Transport Engineers

MANCHESTER
"The Advancement of the Diesel Engine," by H. L. Parrish. North-West Centre. Engineers' Club, Albert Square, Manchester. Mon., Sept. 13, 7.30 p.m.

PRESTON
Film on "The Birth and Growth of a Modern Oil Refinery." North-West Centre. Victoria Station Hotel, Preston. Tues., Sept. 7, 7.30 p.m.

Institution of Heating and Ventilating Engineers

LONDON
"Current American Practice in Heating, Ventilating and Air Conditioning," by J. K. M. Pryke. Institution of Mechanical Engineers, 1 Birdcage-walk, Westminster, S.W.1. Tues., Sept. 14, 6 p.m.

Institution of Production Engineers

BIRMINGHAM
"Abrasives" (with film), by A. C. Turner. Birmingham Graduate Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Tues., Sept. 14, 7 p.m.

LUTON
"Industrial Law: Legal Aspects of Factory and Production Management," by H. P. Jost. Luton Graduate Section. Peahen Hotel, St. Albans. Mon., Sept. 13, 7.45 p.m.

WOLVERHAMPTON
"Some Problems of Higher Technological Education," by the Earl of Halsbury. The 1954 Sir Alfred Herbert paper. Wolverhampton Section. Wolverhampton and Staffordshire Technical College, Wulfruna-street, Wolverhampton. Thurs., Sept. 9, 7.15 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of Petroleum, Manson House, 26 Portland-place, London, W.1. (LANgham 2250.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)

* * *

BONDING METALS

Adhesive Now Available as a Film

Aero Research, Limited, Duxford, Cambridge, have recently introduced their "Redux" adhesive in the form of a film. It has been devised primarily for bonding metal skins to metal honeycombs (as is done in aircraft construction) but can be used for any metal-to-metal bonding.

The film is first consolidated to the metal under heat and pressure, and then a coating of Redux 120 applied. This should also be brushed over the second part and both coatings dried under heat. The two parts are then assembled and curing completed under heat and pressure. Joint strength is said to be about 4,100 lb. per square inch. The film supplies the adhesive materials in proper proportion (avoiding errors in mixing) and is available in rolls. These have a protective covering and a store life of about six months.

Labour Notes

POST OFFICE MEN'S WAGE CLAIMS

Dissatisfaction is being shown by members of the Post Office Engineering Union at the lack of progress which is taking place in connection with the union's claims for improvements in wage rates. The union has a membership of 58,000, most of whom are engaged on work connected with the installation and maintenance of the Post Office telephone system.

In order to inform the union's branches of the steps which their executive committee have taken regarding the claims, and to obtain the views of the rank and file, a series of local meetings, to be attended by leading union officials, has been arranged. The first of these meetings took place in London on Monday. Other meetings will be held during the next few weeks at Brighton, Exeter, Bristol, Reading, Cardiff, Leeds, Liverpool, Newcastle-upon-Tyne, Manchester, Glasgow, Edinburgh, Belfast and Birmingham. In each case, those present will be asked to pledge their support to the executive committee and to demand a speedy settlement.

Many requests have been presented recently by branches of the union for specific action to be taken in support of the claims, such as the calling of a special conference on wages, enforcing a ban on overtime, and organising an appeal to Members of Parliament. There have been no suggestions for strike action to be taken and it is very unlikely, actually, that the executive committee would impose a ban, even a partial one, on overtime.

INTERIM CLAIM PRESENTED

Negotiations were begun in January, when the union presented a claim for improved rates of pay for all telephone engineers, ranging from about 10*s*. a week to approximately £2 a week, according to grade. The claim was based on the higher output per head achieved since the war, comparisons with the pay rates of outside employees doing similar work, comparisons with Civil Service grades performing work of similar skill, and the need to increase the differentials for skill and experience.

Evidence in support of the claim was submitted by the union in an accompanying document, which ran to some 47,000 words.

There was a meeting between representatives of the two sides, but, in June, the Postmaster-General informed the union that he "could not entertain" the claim. The union declined to accept this decision and negotiations have since been re-opened, although nothing approaching a settlement is yet in sight.

Appreciating that the negotiations might take some time, the union presented an interim claim, on June 16, for an all-round increase of 6 per cent., based on changes in rates of pay in industry generally since the union's present rates were settled in January, 1953.

INCREASED PRODUCTION AS A BASIS FOR WAGE INCREASES

In a statement issued last week, Mr. Charles Smith, the general secretary of the union, pointed out that, although the interim claim was perfectly straightforward, there had not been any real discussion on it with Post Office representatives up to the present time.

A reply had apparently been held up because similar claims had been submitted by other Civil Service unions and the Government wished to consider them as a whole before authorising negotiations.

During the discussions on the original claim, suggestions were made by the union for increasing productivity even beyond the improvement of between 16 and 20 per cent. which had been obtained since the war, but the Post Office, Mr. Smith stated, had objected to considering the question in connection with wage negotiations. Later, the Department asked for an amplification of the union's views on this matter. The union presented a memorandum accordingly on April 28, and had heard nothing further.

Another complaint of the union, on which it had approached the Postmaster-General, referred to the increasing tendency for wage claims to be settled by arbitration rather than by negotiated agreements. No wage claim by the union, Mr. Smith said, had been settled by agreement since 1948 and, in every instance, the arbitration tribunal had awarded more than the Post Office had offered. Earlier this year, the union appealed for a new approach by the Department to wage claims. Nevertheless, when difficulties were encountered respecting a claim by the union's motor-transport section, that had to be taken to arbitration just like the earlier claims.

If necessary, the interim claim for a 6 per cent. increase would have to be sent to arbitration, but the union would prefer that both that claim and the major demand should be settled by agreement between the two sides.

THE MINERS' BONUS SHIFT

When the joint negotiating committee for the coal industry commences its meetings later this month, the indications are that the National Union of Mineworkers will seek to obtain the abolition of the "bonus shift," as it now exists, and the provision of some form of sickness benefit for miners, additional to that provided under the national insurance scheme.

The terms of the bonus-shift agreement, which are based on the industry's five-day week, provide that miners who work five shifts in any week shall be paid for six and that men working fewer than five shifts in a week shall be paid only for the shifts actually worked.

Apparently, the union desires that these arrangements shall cease and that payment for each shift shall be increased by one-fifth. This would mean that miners working five shifts would receive the same minimum wages as hitherto and that men working four shifts or fewer would receive one-fifth more money than at present.

The result, for a miner working four shifts, would amount to about 18*s*. more pay, if a surface employee and to £1 more if an underground worker.

The National Coal Board will almost certainly resist this claim, mainly, perhaps, on the ground that the existing arrangements are those most likely to encourage maximum attendances.

Informal discussions on the complicated problem of a new wage structure for the industry have already begun and are expected to be continued for some time before formal negotiations can commence.

HULL DOCK STRIKE ENDED

The unofficial strike of some 4,600 dockers at Hull, which lasted for ten days, rendered 81 ships idle and caused the men concerned to lose around £100,000 in wages, came to a rather abrupt end last Friday, when there was a full resumption of work.

Earlier, by the transfer of a wool ship, a new berth had been found for the Seaboard Enterprise, over which the strike started, and this enabled its cargo of grain to be mechanically discharged at the King George Dock silo. This action did much to bring about the termination of the dispute, which is estimated by the port officials to have cost £500,000 and endangered large quantities of foodstuffs.

Negotiations on the abolition of hand methods for the discharge of grain cargoes at the port are understood to be now in progress.

A QUESTION OF UNIONS

One of the problems left by the recent strike at Hull docks is the question of the union to which the dockers should belong.

During the course of the dispute, there was apparently a fairly general demand among some sections of the unofficial strikers that they should transfer from the Transport and General Workers' Union to the National Amalgamated Stevedores and Dockers.

Mr. R. Barrett, general secretary of the latter union, in a statement on August 26, denied that the N.A.S.D. had agreed to accept the strikers into that union if they left the T.G.W.U. Mr. Barrett said that his union had been in touch with some of the strikers informally, but reports that men were being admitted were based on a misunderstanding of the words of the men's leaders.

In an address to a mass meeting of the strikers on Sunday, Mr. Barrett said that a split vote on membership would be insufficient. At least 3,500 men would have to be in favour of the transfer.

Mr. Barrett said that no inducement had been offered to the dockers to join his union and affirmed that the provisions of the Bridlington agreement had been strictly observed.

RAILWAY WAGE NEGOTIATIONS CONTINUED

In general, discussions on the suggested new structure for the railway industry do not appear to have been carried much further during the past week or so. If anything, the negotiations on this complicated subject appear to have been rendered even more involved by the decision of the Associated Society of Locomotive Engineers and Firemen to follow an independent line of action.

Sir Brian Robertson, the chairman of the British Transport Commission, met leading officials of each of the three railway unions separately on August 24, in accordance with previous arrangements. The last to be seen were the representatives of the A.S.L.E.F., who spent more than an hour discussing their side of the problem with Sir Brian.

According to a statement made later by Mr. J. G. Baty, the general secretary of the A.S.L.E.F., the views of the two sides were irreconcilable and the union had decided not to meet Sir Brian again.

Instead, the union will submit its claim for higher differentials for footplatemen, including a minimum of £10 5*s*. a week for senior engine-drivers to the Railway Staff National Council, which is expected to refer it to the Railway Staff National Tribunal for arbitration.

Although no real progress emerged from Sir Brian's discussions with the other two unions, it was decided that the talks should continue. The leaders of the National Union of Railwaymen and the Transport Salaried Staffs' Association accordingly met Sir Brian again last Friday, when, in the course of his reply to the unions' representations, Sir Brian suggested that joint negotiations on the new wage structure should be resumed, without commitment by either side.

This suggestion has been discussed by the executive committees of the unions and the T.S.S.A. announced on Sunday that it had asked for a further meeting with Sir Brian.